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THE RELATION OF DEFECTS IN ENAMEL COATINGS TO HYDROGEN IN STEEL*

By C. A. Zapffe and C. E. Sims†

Abstract

The effects of hydrogen as functions of time, temperature, and impurities in steel are described and experimentally demonstrated. Experimental evidence is presented to show that the blistering and boiling action over carbide areas in steel are due principally to hydrogen that associates with the carbon. Steel enameling stock contains quantities of hydrogen which may effuse during firing to cause or aggravate such phenomena as "boiling," "primary boiling," "reboiling," "blistering," and "bubbling." Low-temperature effusion of hydrogen contributes to other defects, including "fishscaling," "delayed fishscaling," and possibly "pop-offs," "jumping," "shiners," and some cases of "chipping" and, perhaps, "bursting" of enamel on cooking utensils. These defects have seldom been identified with hydrogen evolution. An indirect effect of hydrogen on "copperheads" and "black specks" is also identified.

An exhaustive review of both English and German literature on enameling defects is included. Many observations recorded in the literature are shown to agree with the hydrogen theory.

Certain types of inclusions in steel are shown to react with occluded hydrogen to form compounds that will not dissociate appreciably at some enamel-firing temperatures, and critical quantities of the hydrogen are therefore prevented from reaching the enamel coating during firing to cause blistering and related defects.

I. Introduction

In view of recent important metallurgical work on hydrogen in steel, an examination of the literature on enameling defects indicates a possible correlation between such defects and the presence of hydrogen. The failure to identify hydrogen as a most important source of these defects may be attributed to the ambiguity that has attended the complex behavior of this gas in steel, but the known ease with which absorbed hydrogen embrittles and ruptures steels and the fact that this gas is apparently as omnipresent in steel as the element carbon should have attracted more suspicion than has been accorded.

A brief discussion‡ of the metallurgical aspects of hydrogen in steel is first presented to aid in understanding the experimental work and hypotheses that follow. An exhaustive review of the English literature and the past ten years of the German literature on enameling defects is included. Over two hundred references are contained in the bibliography, which includes only references on enameling defects. The many unanswered, and sometimes wrongly answered, questions that stand in this mass of literature are shown to be largely answerable from the standpoint that hydrogen contained in the steel either directly or indirectly causes the particular defect.

It is the purpose of this paper to discuss the relationship between hydrogen and many of the defects that plague the enameler. It would be wearisome to the reader if, in every section, a paragraph were inserted to say that the particular defect under discussion may be wholly or partly produced by a variety of other factors. Such factors as dust in the shop atmosphere, wrong weight of enamel applied, wrong fineness of grinding, wrong choice of dispersing agents, opacifiers, etc., enter into the production of many defects. In the various cases where hydrogen is shown or suspected to be an agent, it is naturally not necessarily the sole or most important one. It is not the task in hand to deal with all causes of defects or to consider the relative importance of every one of a group of multiple causes. Let this paragraph be understood as applying to all that follows.

II. Theoretical Considerations of Hydrogen in Steel

(1) "Irreversible" Molecular Occlusion

Perhaps the most remarkable single feature of the steel-hydrogen system is the ability of hydrogen to collect under tremendous pressure within discontinuities in the steel, whether these discontinuities be blowholes, inclusions, macroscopic cracks, and grain boundaries or rifts in the submicroscopic structure. The explanation of the phenomenon lies principally in the two facts that hydrogen dissolves in steel only as the nascent or atomic gas, H (not as the molecular gas, H_2),

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‡ For a more detailed discussion of the fundamental metallurgical aspects of hydrogen in steel, see "Flakes, Shatter Cracks, and Hydrogen in Steel" by the present authors published in *Metals and Alloys*, **11** [5] 145–51 (1940). All statements of a metallurgical nature made in the present paper have been excerpted from the former, and their authorities may be found in that paper.

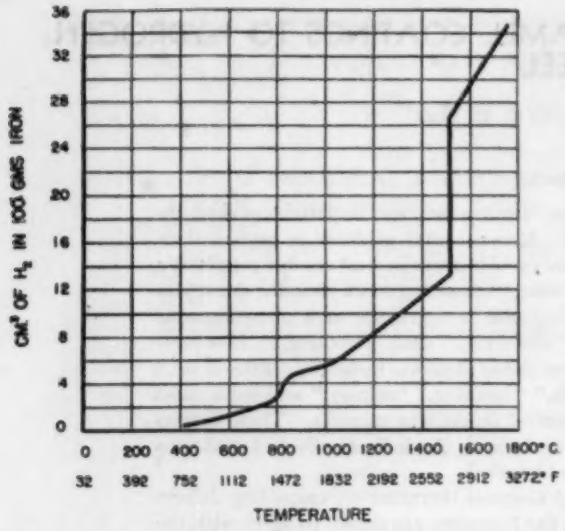


FIG. 1.—Variation of the (reversible) solubility with temperature for hydrogen in iron at one atmosphere pressure (Sieverts).

and that the solubility of the gas decreases several thousand-fold from melting temperatures to room temperature.

The variation of solubility with temperature for hydrogen in pure iron is shown in Fig. 1. Below 400°C. (750°F.), the amount of hydrogen in true solution becomes immeasurably small. The solubility varies with the square root of the pressure at constant temperature (Fig. 2), conforming to the mass-action law:

$$H_2 = 2H$$

$$K_H = \frac{(P_H)^2}{(P_{H_2})}$$

$$P_H = K'_H \cdot (P_{H_2})^{1/2}.$$

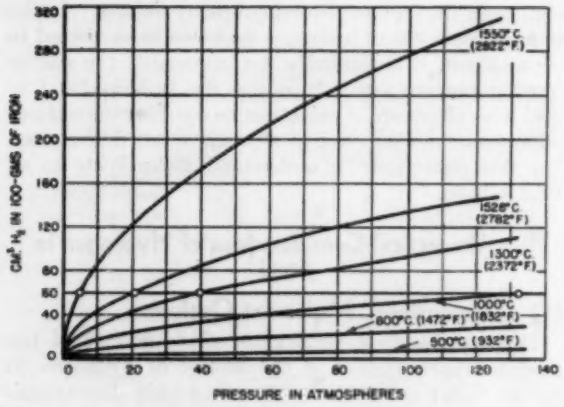


FIG. 2.—Relation of the (reversible) solubility to pressure for hydrogen in steel (Bardenheuer and Keller).

This relationship proves that the gas dissolves only atomically. Other researches have clearly demonstrated that the atoms are held interstitially in the iron lattice. The imperviousness of steel to molecular hydrogen is demonstrated by the fact that steel tanks are used for containers of hydrogen; and it has been shown experimentally that to force molecular hydrogen through steel requires pressures exceeding the elastic strength of steel.

It is evident that the sharp decrease in solubility that occurs with decreasing temperature (Fig. 1) will cause a high degree of supersaturation to obtain when steel is cooled, even though the solution at the elevated temperature was dilute. To hold the excess atomic gas in solution in the metal, an equal pressure of atomic hydrogen is necessary outside the metal lattice. As the decrease in solubility is about one thousand-fold from the firing temperature of porcelain enamel to room temperature, roughly one thousand-fold increase in the partial pressure of atomic hydrogen would be required to prevent precipitation of hydrogen in a cold steel that had been previously saturated at the firing temperature. At ordinary temperatures, however, hydrogen is so extremely stable in the molecular state that unattainable total pressures of the gas would be necessary to provide this required partial pressure of atomic hydrogen. In addition, increased pressure favors still further the formation of molecular hydrogen as there is a volume change.

Dissolved hydrogen, therefore, will diffuse out of the metallic lattice almost without hindrance; and, when this escape takes place at an *internal* surface, the escaping atoms will recombine to form molecular hydrogen in the discontinuity until the equilibrium pressure is attained or the metal ruptures. Such "trapping" is especially favored by the fact that diffusion is extremely slow at ordinary temperatures and escape at external surfaces scarcely affects the concentration of gas at internal surfaces.

Simple calculations of these potential internal pressures, using the solubility values from the curve in Fig. 1, result in the curves shown in Fig. 3. It is seen that considerably less than 0.001 weight per cent of hydrogen in steel can produce pressures at ordinary temperatures that exceed the strength of the steel. Accordingly, it has been amply demonstrated that hydrogen can rupture the strongest steel.

Appreciating the comparative insignificance of the pressure that would be required to raise a blister in fused enamel, it is clear that the most minute trace of hydrogen in steel should be regarded with suspicion; and although special treatments may remove a large portion of the gas, their results should never be regarded as being absolute.

(2) Sources of Hydrogen in Steel

Referring again to Fig. 1, it is evident that the commonest source of hydrogen is probably in the melting procedure, as very dilute solutions in liquid steel may still provide supersaturated cold stock owing to the great change in solubility with temperature. Sources of hydrogen in the steel-making process are numerous, such as combustion gases, humidity of the air, moisture in the raw materials, and water combined chemically with the charge. For example, the addition of just

1% of rust to a bath of steel provides about 20 volumes of hydrogen (S.T.P.) per volume of steel, which is approximately the saturation value for liquid steel under one atmosphere pressure of pure hydrogen. Moisture readily dissociates in contact with iron at elevated temperatures and provides two atoms of hydrogen for every atom of oxygen that combines with the iron. The significance of the moisture content of the air is illustrated in recent work with an "air-conditioned" blast furnace, wherein it was observed that water carried into the furnace by the blast varied from 72 gallons per hour in winter to 1000 gallons per hour in summer. It is fairly well accepted by metallurgists that steel made in damp weather tends more to hydrogen defects than steel made in dry weather, and it is interesting to note in the literature on enamel defects that a few investigators have suspected a similar relationship in regard to the reboiling of enameling stock.*,[1] Many enamelers have suspected the steel-making process[2] though they have not identified the mechanism.

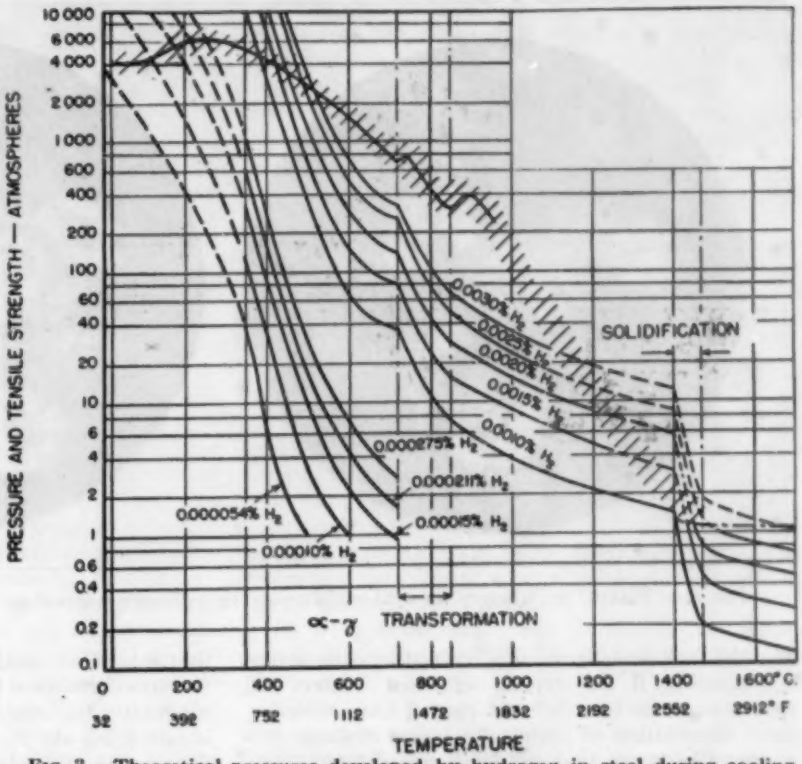


FIG. 3.—Theoretical pressures developed by hydrogen in steel during cooling (Luckemeyer-Hasse and Schenck). All of the curves represent pressure developed by hydrogen, except the shaded line which represents the tensile strength of cast steel.

Examples of metallurgical defects notably caused by hydrogen remaining in steel from the melt are the "flakes" that occur in forgings and the "shatter cracks" that occur in rail steels. Figure 4 shows another common defect, a large blister on unpickled steel sheet caused by hydrogen inherited from the melt.

If finished steel stock does not contain an important quantity of hydrogen, whether for reasons of good melting practice or favorable treatments, hydrogen may enter the steel in many ways subsequent to finishing. Welding introduces a great deal of hydrogen to steel, for hydrogen is copiously contained in cellulose coverings, in gas-weld atmospheres, and in attendant moisture. Figure 5 shows an outstanding instance of "flakes," or "fisheyes," caused by hydrogen in weld metal. The cavities that trapped the gas are readily visible; and the radial cracks, extending from the cavities into the steel and the surrounding embrittled zone, reveal the tremendous volume and pressure of the gas that had been occluded there. Enamelers have had a great deal of trouble applying coatings to weld metal.[3]

At ordinary temperatures, one of the most common reactions that supplies hydrogen to steel is rusting, whereas the greatest quantities, and the most rapid absorption of the gas, are obtained from pickling or cathodic electrolysis. Any action that provides nascent hydrogen at the surface of the steel will cause absorption of this hydrogen, and at ordinary temperatures steel shows a remarkable ability to occlude the gas, probably molecularly in internal, submicroscopic rifts. Cold-working the steel causes these rifts to increase in size and number with the result that a specimen may take up hydrogen in quantities thousands of times greater

FIG. 4.—Blister on unpickled steel sheet caused by hydrogen inherited from the melt.

*Numbered footnotes refer to Bibliography references, pp. 215–19.

[1] 196, 213.

[2] 25, 27, 28, 87, 95, 114, 125, 181.

[3] 57, 120, 121, 192.

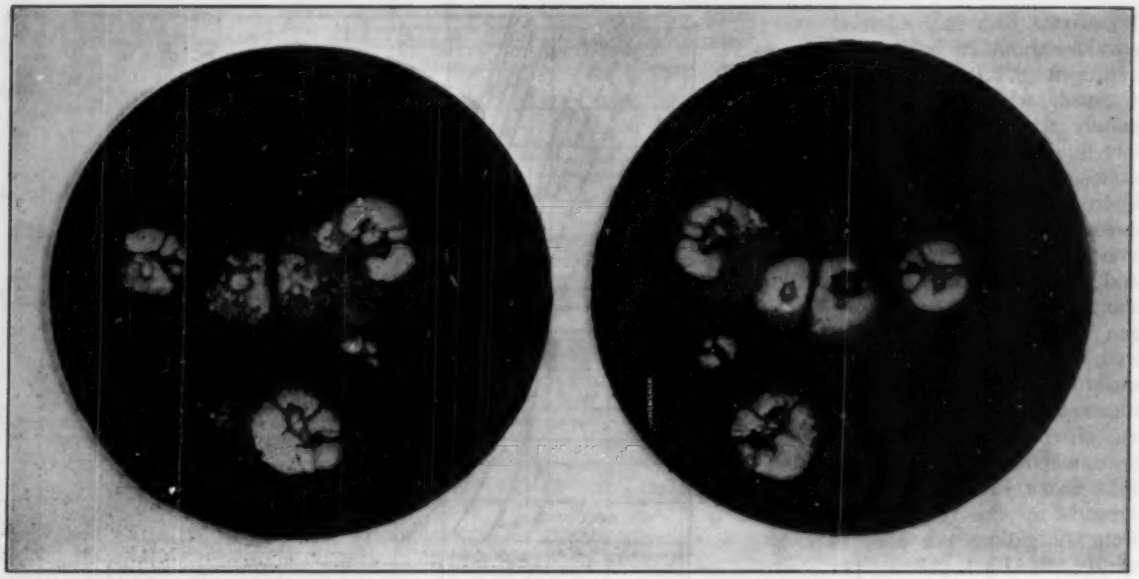


FIG. 5.—"Flakes" or "fisheyes" in weld metal caused by hydrogen trapped during welding (tensile specimen).

than the true solubility.[4] It is interesting to note that in enameling, if the steel is scratched, blisters will appear over the scratch.[5] At enamel-firing temperatures, dissociation of chemically bound moisture is a source of hydrogen that will be discussed later.

When the gas precipitates molecularly in the minute rifts just mentioned, very little precipitation need occur to provide a high aerostatic pressure, and the great dispersion of these rifts causes the cumulative effect to exhibit itself as general embrittlement of the steel. When precipitation occurs at larger loci, for example, at inclusions, cavities, and grain boundaries, the pressure does not increase so readily and no noticeable deterioration need occur. The volume of the occluded gas then becomes an important factor, especially in enameling practice, because at firing temperatures molecular hydrogen dissociates quite rapidly in the presence of iron and is then free to re-diffuse into the steel. The consideration of this trapping, storing, and re-diffusion of hydrogen at enamel-firing temperatures provides the basis for this paper.

Aging and low-temperature annealing are popularly supposed to drive hydrogen out of steel. So the treatment does, but *only* that hydrogen which is in true, reversible solution or that which is in exceedingly small rifts where the ratio of surface to volume is very large. Otherwise it may be generally stated that hydrogen occluded in steel will remain in the steel until heated to about 800°C. (1450°F.), where dissociation in the presence of iron first becomes fairly rapid. At this temperature, however, a strong increase in the solubility occurs (Fig. 1), and the hydrogen liberated from the cavity or inclusion is no longer so pressed to leave the steel but will proceed instead to saturate the lattice surrounding the discontinuity. The complications that may result should now be evident. For example, the transformation from alpha to gamma, and concomitantly the solubility increase, in ordinary enameling stock lies well above the temperature at which rapid diffusion of molecular hydrogen occurs. As the specimen heats during firing, some dissociation will occur before the solubility has markedly increased, and the released hydrogen will diffuse rapidly out of the cavity and seek the surfaces of the steel, there to collect perhaps under the freshly fused enamel and raise first a wrinkle, from the general effusion, and then a blister,*[6] for reasons of surface tension. The lag in heating the steel aids this effect. But, as the specimen comes to the temperature of the furnace, the solubility of hydrogen in steel so markedly increases that the gas is able to redissolve, and the blister disappears.[7] When cooled, the specimen will contain a region supersaturated with hydrogen, part of which will find its way again to the cavity to be available for "reboiling" and the other part will seek the surface of the piece, perhaps to cause "fishscaling" and "chipping." Oddly, the hydrogen theory was discarded by many enamelers because it did not account for the cyclic nature of reboiling.[8]

The difference between the responses of dissolved and of occluded hydrogen to annealing at low temperatures has apparently confused the issue of hydrogen in enameling defects. Most enamel plants have modified their procedure for preparing stock for enameling so that hydrogen absorbed during the pickling process is eliminated, but the methods of elimination have been

[4] 107. [5] 211.

* The term, "*cf.*," preceding reference numbers is used to show that in these articles there are data which corroborate the present theory but without recognition by their authors.

[6] *Cf.* 174.

[7] *Cf.* 102, 112, 174, etc.

[8] 102, 126.

based on the supposition that all hydrogen in steel is reversibly dissolved and is rapidly removed by low-temperature annealing.

There are other complicating reactions that retain hydrogen in steel in addition to the formation of molecular hydrogen at discontinuities, for hydrogen is strongly attracted by many other elements than iron, especially when the hydrogen is atomic. When impurities in steel are segregated as inclusions, the atomic hydrogen at the moment of precipitation in the inclusion may react with the material of the inclusion to form products more (or less) stable than molecular hydrogen, and temperature functions will be distorted according to the stability of the compound in contact with iron. On the other hand, the impurity, such as carbon, may be molecularly dispersed. It is known that cementite is unstable and that the carbon-hydrogen bond is very strong. Experiment corroborates theory to show that hydrogen is retained by carbon in steel probably in the form of a quasi-methane structure. The formation of methane from atomic hydrogen ostensibly entails a fourfold volume decrease and would thereby effectively decrease the precipitation pressure. As carbon-hydrogen structures decompose quite completely at about 600°C. (1100°F.), hydrogen may be liberated in a considerable fraction at this temperature. Whether or not the hydrogen then leaves the steel depends of course on the nature of the contact of atom to metal lattice at the moment of decomposition. If the contact is not good, molecular hydrogen will form.

From this brief discussion it is evident that, although the hydrogen–iron system is amenable to prescribed treatments, the hydrogen-steel system is more complex and will therefore not yield to treatments designed to remove hydrogen from iron except in a rough, qualitative way. It can only be said, summarily, that hydrogen in steel will behave with changing temperature about as follows:

(1) At room temperature, the fraction of hydrogen that is in actual solution or is precipitated in submicroscopic rifts will slowly diffuse out of the specimen, several days being required to effect a significant change except in very thin specimens. The rolling or banded structure in sheet steel further prohibits this effusion, as will be shown.

(2) At temperatures of 100° to 300°C. (200° to 550°F.), roughly, the same effusion in (1) will occur in a matter of minutes, as the rate of diffusion of hydrogen in iron increases logarithmically and very rapidly with increasing temperature. All other fractions of hydrogen remain quite unaffected.

(3) At temperatures above 400°C. (750°F.), quasi-methane structures will break down to free hydrogen either in a diffusible or an indiffusible state, depending on the nature of the segregation.

(4) At approximately 800°C. (1470°F.), trapped molecular hydrogen will dissociate and re-diffuse into the iron.

(5) At higher temperatures, hydrogen compounds that are more stable in contact with iron than molecular hydrogen will dissociate.

The story of hydrogen in enameling stock may also

FIG. 6.—Hydrogen evolving from a $^1/_8$-inch steel wire placed in previously boiled water at 95°C. (200°F.) after 10 minutes pickling in warm dilute sulfuric acids. After immersing: (*left*) 30 seconds; (*middle*) 5 minutes; (*right*) 10 minutes.

be briefly summarized as follows. Hydrogen liberated from occlusion during firing will first spread through the steel surrounding the discontinuity. A portion of the gas may find its way to the surface of the piece to cause blistering depending on the location of the discontinuity. If the steel comes to temperature before the hydrogen reaches the surface or if the re-solution is delayed for some chemical reason until the steel has transformed to face-centered-cubic gamma, a more active solvent, the freed hydrogen may merely dissolve in the metal lattice and need not leave the specimen in appreciable quantities until the temperature is lowered and the decreased solubility again forces the gas out of the lattice. A portion will then find its way out of the steel and another portion will return to the cavity. This fraction of occluded hydrogen thus serves to provide recurrent local supersaturation. In the fabrication of steel products, such recurrence is evidenced in the occasional reappearance of "flaking" and other hydrogen-caused defects; in enameling, the analogous phenomenon is termed "reboiling." In every case, of course, successive appearances of the defect are progressively mitigated because the hydrogen gradually disperses and ultimately leaves the steel.

When the enamel has hardened, the precipitation at the metal-enamel interface of hydrogen released into the steel at firing temperatures creates local pressures that lead to "fishscaling" by the same means that blisters were raised at higher temperatures.

(3) Experimental Observations

The following experiments illustrate the preceding arguments.

The effects of hydrogen inherited from the steelmaking process and from welding have already been illustrated in Figs. 4 and 5. The magnitude of hydrogen absorption from pickling, however, is so great that in comparison other sources are almost unimportant, Figure 6 shows the surprising quantity of hydrogen that a small steel wire will absorb during the ordinary pickling procedure used in preparing steel for enameling. The rod has been pickled only ten minutes in dilute sulfuric acid, rinsed, and immersed in previously boiled water heated to 95°C. (200°F.), to accelerate diffusion. Such an effusion, continuing as shown for more than ten minutes, is, to say the least, remarkable. An attempt to apply a coating of Glyptal lacquer to such a specimen naturally failed.

Figure 7 shows the bottom of an iron crucible that has been coated with Glyptal. Dilute sulfuric acid inside the crucible generated hydrogen which diffused through the iron, formed molecular hydrogen underneath the lacquer, and formed blisters (note the size of the blisters). The strong effect of permeability of the coating on regulating the severity of blistering is evident in the comparison of Fig. 8 with Fig. 7. Figure 8 shows the same crucible bottom coated with a viscous white paint, and it is seen that the blistering is much more acute. The analogy to vitreous enamel coatings is important.

When the coating is rigid and hard, the blistering action naturally becomes a rupturing action, identified in enameling practice as "fishscaling" and perhaps "chipping," "pop-offs," etc. An unusually severe instance of this type, artificially produced, is shown in Fig. 9. Dilute sulfuric acid inside a porcelain-enameled pan provided hydrogen that penetrated into the metal underlayer in much the same manner that internal reactions of steel at elevated temperatures with hydrogen in discontinuities produce supersaturation according to principles already discussed. The inside of the pan was scraped bare of enamel to permit acid reaction with the iron. The hydrogen diffused through the pan and recombined at the submicroscopic metal-enamel interface to form pressures of molecular hydrogen that literally exploded the enamel from the pan and threw pieces as far as six feet. The litmus paper (Fig. 9) was used to show that no trace of acid had seeped through the metal at any point and that the pressure was generated only by hydrogen that had diffused

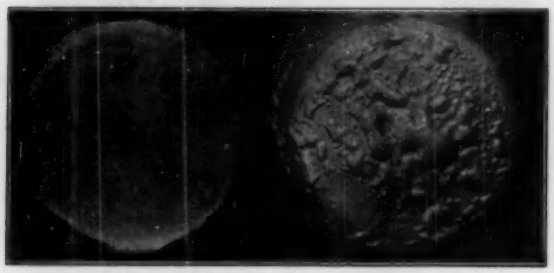


FIG. 7 (*left*).—Coating of Glyptal on bottom of iron crucible that contained dilute sulfuric acid, showing blisters caused by hydrogen that has diffused through the crucible.

FIG. 8 (*right*).—Same crucible coated with ordinary white paint.

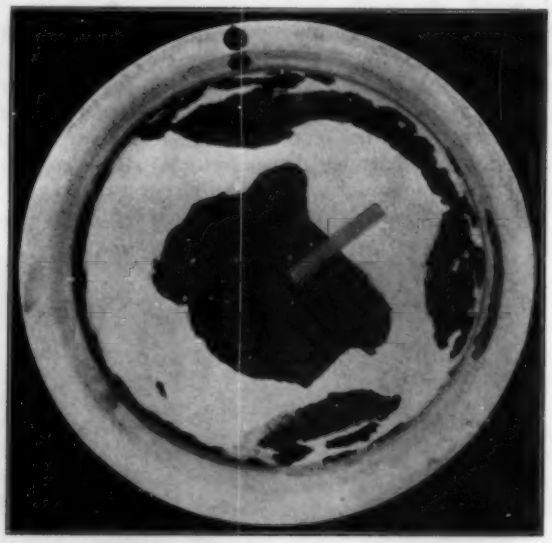


FIG. 9.—Bottom of porcelain-enameled pan showing enamel exploded away by hydrogen that had diffused through pan (note litmus paper).

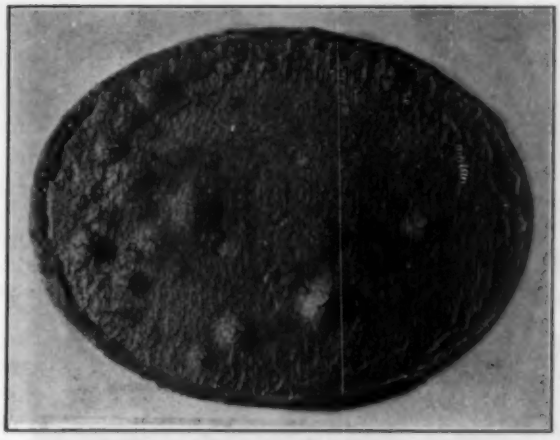


FIG. 10.—Blisters in 1/8-inch steel caused by hydrogen derived from pickling.

through the iron in the manner already discussed. A preferential rupture of the cover coat is evident, indicating that the ground coat in this case is more permeable to hydrogen than the cover coat. The pressure center thus often transfers from the metal-enamel interface to the interface of the two coatings, thereby accounting for the perplexities among enamelers who have tried to find the reason that scales and chips are variously seated in the coating.

An idea of the practically limitless power of precipitating hydrogen may be gained from Fig. 10. Two 1/8-inch steel plates were cleaned and welded together around their peripheries, heated to 1200°C. (2200°F.), and rolled to a small reduction. Care was taken not to oxidize the interface more than would result from a thin layer of adsorbed air. The compound disk was then pickled in dilute sulfuric acid until blisters appeared. From the photograph, it is evident that most of the area of the interface welded together. Where an oxide film remained, however, hydrogen, generated during pickling, was halted during diffusion, and pressures resulted that blistered the steel over these areas. The force required must have been several thousand pounds per square inch.

An apparatus for measuring the pressure developed by hydrogen diffusing into an artificial cavity in steel is shown in Fig. 11. A solid steel cylinder was drilled longitudinally and the open end was fitted with a high-pressure gauge. As cathode in an electrolytic bath, the steel quickly absorbed hydrogen, which diffused through the steel, into the cavity, and there created pressures that increased rapidly and without apparent hindrance from the constantly accumulating back pressure of molecular hydrogen. When thirty-two atmospheres pressure had been obtained, the gasket around the gauge ruptured and the test was discontinued. Pressures of more than 300 atmospheres have been similarly obtained by other investigators, but such experiments are limited because they become dangerous.

It can be appreciated that the effects of hydrogen in steel are strong functions of time as well as temperature. This is illustrated in Fig. 6, for a coating could obviously be satisfactorily applied if sufficient time had elapsed after pickling. It would be interesting to find the approximate stage of the evolution of hydrogen shown in Fig. 6 at the time the raw enamel is applied. Figure 12 therefore shows a similar rod which has been given approximately the following standard procedure used to prepare all steels in this research for enameling:

(1) Wyandotte No. 5 Perfection Cleaner; 4.5% solution (90 gm. in two liters of distilled water) at 77°C. (170°F.) for 15 minutes.
(2) Rinsed in tap water at about 75°C. (170°F.) for 3 minutes.
(3) Pickled in 5% H_2SO_4 solution (85 cc. of H_2SO_4, density = 1.84, in 3 liters of distilled water) at 65°C. (145°F.) for 15 to 30 minutes, as required.
(4) Rinsed in tap water at about 75°C. (170°F.) for 3 minutes.
(5) 0.5% Na_2CO_3 neutralizing solution (10 gm. anhydrous Na_2CO_3 in 2 liters of distilled water) at 70°C. (155°F.) for 5 minutes.

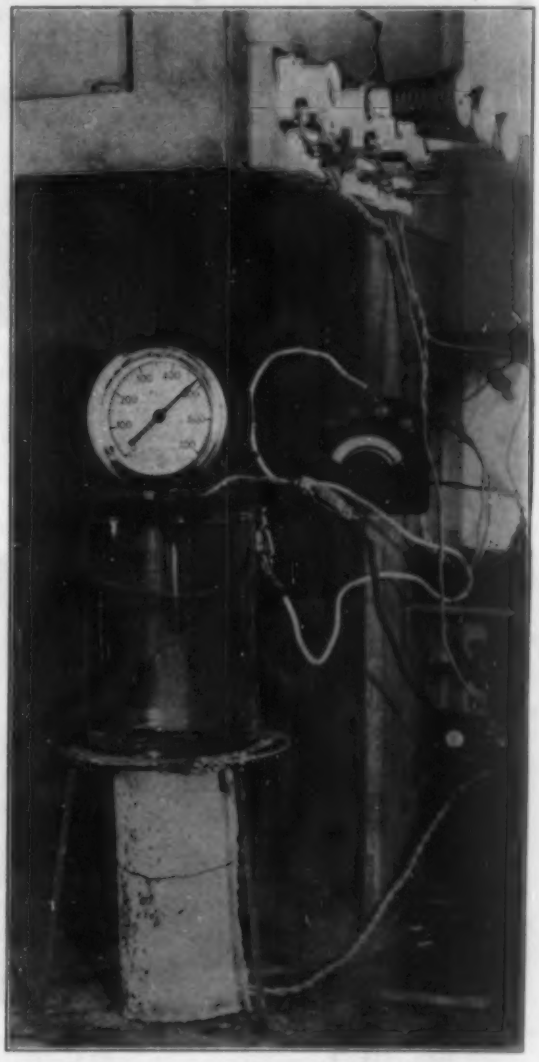
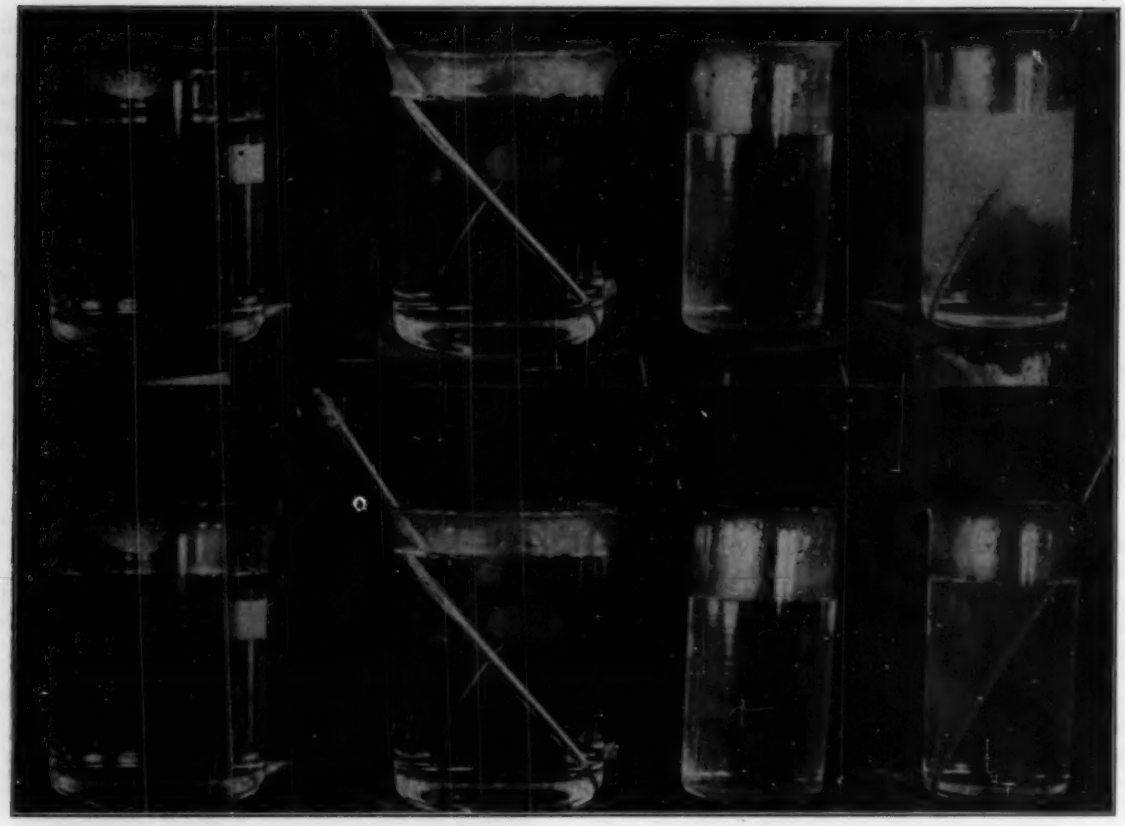
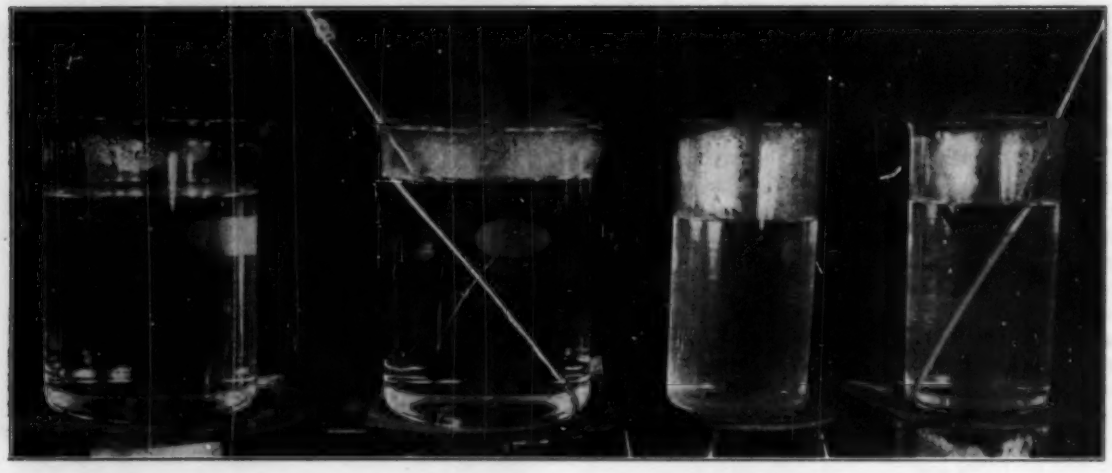


FIG. 11.—Gauge registering pressure of molecular hydrogen trapped in artificial cavity in a steel cylinder during electrolysis.



5% H_2SO_4	Water rinse	0.5% Na_2CO_3	Water
65°C. (145°F.)	75°C. (170°F.)	70°C. (155°F.)	95°C. (200°F.)
10 minutes	2 minutes	2 minutes	

FIG. 12.—One-eighth inch rod immersed in water (as in Fig. 6) after standard preparation for enameling. (*Upper*) immediately after immersion; (*lower*) 6 minutes later.



5% H_2SO_4	Water rinse	0.5% Na_2CO_3	Water
60°C. (140°F.)	90°C. (195°F.)	90°C. (195°F.)	95°C. (200°F.)
8 minutes	4 minutes	6 minutes	

FIG. 13.—Same rod as in Fig. 12 prepared by slightly modified procedure.

(6) Dried at 115°C. (240°F.) for various periods, as noted.
(7) Sprayed, or dipped, with various enamel slips, as noted.
(8) Baked at 115°C. (240°F.) for various periods, as noted.
(9) Fired at temperatures as noted.

Instead of applying the enamel coating, however, the procedure was interrupted after step (5), and the rod was immersed as before in plain hot water so that the effusion of gas would be made visible. Although appreciably less than that shown in Fig. 6, the effusion is certainly most significant. By changing slightly the temperatures and periods of time of the various parts of the procedure to minimize the hydrogen absorption during pickling and to provide the dissolved hydrogen with more time to diffuse and more rapid diffusion in post-pickling operations, the results shown in Fig. 13 can be obtained. Here the turbulent effusion has been completed while the specimen was in the neutralizing and rinsing baths. As a result, the coating is applied on a surface that no longer evolves gas. This evolution, it will be recognized, comprises only hydrogen, that was atomically dissolved or retained in submicroscopic rifts.

Enamelers, however, apparently have recognized this type of evolution, and the drying periods before coating and before firing rid the specimen quite effectively of such dissolved hydrogen. Correspondingly, blistering and scaling of enamels has been greatly minimized in recent years. Nevertheless, it has been amply pointed out in the previous discussion that low-temperature annealing will not eliminate occluded hydrogen from the steel, and the best published enameling procedures still fail to effect complete elimination of defects that are caused by these remanent insoluble portions of hydrogen.

Numerous other experiments have been made to show the astounding effects produced upon steel by hydrogen, but these few should be sufficient to convey the information and significance necessary to appreciate fully the effect of hydrogen in the following experiments with vitreous enamel coatings.

III. Relation of Hydrogen in Steel to Enameling Defects

(A) Blistering and Boiling*

(1) Introduction

Metallurgical literature contains a redundance of names for the fissures in steel that have recently been shown to be caused by hydrogen. It should not be surprising, therefore, to find that the literature on enamel contains a similar array of defects for which no satisfactory cause or relation has been found. This long list of enameling defects may be considerably foreshortened and interrelated when considered with an understanding of the anomalous functions of hydrogen in iron and steel.

* As it is impractical to list in a title all of the nomenclature that has accumulated for defects that will soon be shown to be closely related, representative terms have been selected without regard for their closer definitions.

It has just been explained that any heterogeneity whatsoever in steel, whether it be a fissure, a blowhole, an inclusion, a grain boundary, or an alloying element, that is metastably held, will collect large quantities of hydrogen and will retain this hydrogen until the steel is heated to some elevated temperature. In the case of sheet-steel enameling stock, hydrogen will be inherited from the steel-making process[9] (refer to Fig. 4), and this quantity may be subsequently increased (1) during the scale-removing pickling operations prior to cold working[10] (Fig. 5), (2) during the pickling in the cleansing operation for enameling[11] (Fig. 12), (3) by ordinary rusting reactions with moisture,[12] (4) during enamel firing by the reaction of the iron with chemically combined moisture in the slip[13] or with steam in the furnace atmosphere,[14] or (5) by direct absorption from gases in the furnace.[15] The behavior of occluded hydrogen has been amply discussed, and it is evident that hydrogen, even in a hypothetical, perfectly pure and homogeneous iron wherein occlusion could not occur, still demands careful consideration because diffusion at ordinary temperatures is exceedingly slow and solubility at elevated temperatures becomes very great.

Actual analysis has shown that enameling stock contains important quantities of hydrogen[16] and that more will be absorbed during firing.[17] Many present-day writers continue to express gas analyses in weight per cent and then proceed to dismiss hydrogen as an important consideration because analysis shows less than half as much (by weight) hydrogen as there is nitrogen, oxygen, or carbon dioxide or because the figure is so insignificant compared to that of iron. Actually in such analyses there is, respectively, 14, 16, 22, and 28 times as much molecular hydrogen as credited (twice these quantities of atomic hydrogen!), and it immediately follows that hydrogen is often the predominating gas by direct analysis. Then the fact should also be considered that important fractions of hydrogen may escape analysis either by diffusion from the steel before the analysis or by virtue of the impotence of vacuum technique, which must operate against a most effective square-root relationship in abstracting at elevated temperatures the now highly soluble gas. In addition, most other gases exist in the steel as solid phases, which do not show the anomalous behavior that characterizes hydrogen; in fact, such solids as oxide inclusions, etc., can hardly be regarded as part of the gas content of the steel, at least of the solid steel, and even in liquid steel an important fraction is present as dissolved solids and as chemical or mechanical suspensions.

[9] *Cf.* 25, 27, 28, 87, 95, 114, 125, 181, 196, 213.
[10] 167.
[11] *Cf.* 3, 13, 32, 37, 48, 59, 64, 66, 89, 92, 96, 107, 121, 124, 135, 142, 162, 164, 167, 186, 189, 190, 193, 197–99, 211, 217–19.
[12] *Cf.* 17, 114, 126, 133, 149, 175, 178, 214, 218.
[13] 186, 197–200, 212, 218, 219.
[14] 197–199, 218, 219, *cf.* 10, 54, 56, 98, 99, 104, 126, 136, 141, 157, 175, 215.
[15] *Cf.* 10, 53, 54, 56, 126, 136, 157, 175, 218.
[16] 78, 198, 199.
[17] 197, 198, 212.

It is interesting that the earliest writers on enameling defects suspected gases contained in the steel to be the source of the defects[18] and that many writers have suspected hydrogen[19]; whereas only during the last few years has proof been advanced that hydrogen is the malefactor,[20] and none of this work appears in English literature. The reasons that hydrogen was not identified long ago are those just mentioned, viz., (1) analysis for hydrogen is so difficult that results have always given deceptive minimum values, and (2) analyses have been expressed only in weight per cent and without regard for simple chemical relations.

Enamelers have published little on hydrogen as a cause of enamel defects. King,[21] for example, dismissed consideration of hydrogen with brief mention of Baker's inconclusive findings in 1918 and a comment on the fact that Hayes, Canfield, and McGohan[22] reported finding only 0.0008 weight per cent of hydrogen in enameling stock. Atom for atom, hydrogen to iron, there is just fifty-six times as much hydrogen in that analysis as represented so unfortunately by the figure 0.0008 weight per cent. Referring to Fig. 3, it may be seen that a steel containing 0.0008 weight per cent hydrogen may be stressed beyond its breaking point by this amount of gas; and it is true that steel showing the internal breaks referred to as "flakes" and "shatter cracks" often analyzes less than 0.001 weight per cent hydrogen.

Enameling stocks contain hydrogen in quantities that vary widely from stock to stock, and these inherent quantities are greatly enhanced during firing by reaction of the iron with chemically combined moisture in the enamel. For example, Kerstan[23] found that stock containing 0.00022 weight per cent hydrogen before firing, analyzed 0.00098 weight per cent hydrogen after firing. Hoff and Klärding[24] and Klärding[25] show that enamel analyzes about 1% H_2O after drying for ten hours at 125°C. (260°F.) and that this combined water is a prolific source of hydrogen to the steel during firing.

It is therefore evident that hydrogen must be considered in regard to enameling troubles, for, if the gas effuses from the steel during firing at a time when the enamel is in a certain state of pastiness, blisters will be formed in the viscous enamel; if the effusion occurs when the enamel has hardened, the gas will collect under pressure at the enamel-metal interface; and, if the coating is not sufficiently permeable, chipping of the enamel will occur.

The latter type of phenomenon recognized in enameling as "fishscaling" and possibly "chipping," "jumping," "pop-offs," "crystallites," etc., will be discussed later. Effusion of gas during firing to form blisters in the enamel has been variously dubbed "boiling," "primary boiling," "blistering," "bubbling," and "reboiling," which terms are undoubtedly differentiated much more than is necessary. All are characterized by the formation of blisters in the enamel and are unique principally in the time of their occurrence.[26]

The most discussed of the group is perhaps the "reboil blister,"[27] which often seems to depend on a previous firing for its appearance.[28] The cause of reboiling is admittedly not known,[29] but the accepted explanation in this country is that carbon in the iron reduces oxides in the slip during firing to produce gaseous carbon oxides.[30]

Examining the observations contained in the literature on blister-type defects, there is a most remarkable congruence with every observation that should be expected if the hydrogen activities previously outlined are understood. Before comparisons are drawn, however, the writers wish it to be understood that they do *not* disclaim the fact that some blistering may result from carbon-oxygen reactions, from liquids that have seeped into surface irregularities, and from other minor reactions and miscellaneous shop defects. The writers contend only that hydrogen is very likely to be the major cause of the blistering that appears during firing porcelain enamels on iron or steel and that, whatever its order of importance, some important functions of hydrogen in enameling stock have not yet been recognized by the enameling industry, particularly in this country.

Take, for example, some of the points in the excellent summary on reboiling provided by Lord.[31] First, he states that reboiling commences suddenly as the piece reaches a dull red heat, lasts for a few seconds and then subsides, and *will not occur again until the piece has been first cooled to nearly room temperature.*[32] Such an observation conforms perfectly to the hydrogen theory, for it will be recalled from the work outlined in the first part of this paper that hydrogen occluded in the steel is released from its localized positions when the steel approaches a dull red heat. Diffusibility is rapid and the solubility remains low while the iron is still body-centered cubic. The released hydrogen will diffuse through the steel and, if near enough to the surface, will effuse at the metal-enamel interface to cause first a wrinkling and then blistering according to simple laws of surface tension. Connelly and Lord[33] observed this process with a suitably arranged microscope, and the inception of blistering that they observed 15 to 40 seconds after inserting 20-gauge stock in a furnace at 875°C. (1600°F.) again conforms with what one should expect from hydrogen diffusing from within

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[18] 2, 3, 7, 13, 27, 37, 48.
[19] 2, 3, 12, 13, 37, 48, 53, 64, 84, 88, 95, 121, 167, 178, 190, 193, 194.
[20] 92, 107, 124, 184, 186, 189, 197–200, 212, 218, 219.
[21] 101. [22] 78.
[23] 199. [24] 198. [25] 212.
[26] 1–3, 11, 13, 16, 17, 20, 22–28, 35, 37, 44, 45, 47–49, 51–62, 67, 69–72, 75–79, 85, 87, 88, 90, 91, 93–105, 109, 110, 112–114, 117, 118, 120–122, 125–129, 131, 133, 134, 136, 137, 141, 143, 146–150, 153, 154, 158–162, 164, 167, 169, 171, 173–176, 178, 181, 188–190, 192–194, 197, 203, 205, 206, 208, 209, 211, 213–216, 218, 219.
[27] 53, 54, 62, 78, 85, 89, 96–100, 102, 103, 110, 112, 118, 126, 127, 131, 134, 146, 147, 157, 161, 162, 174, 175, 208, 211, 218.
[28] 126, 175.
[29] 126.
[30] 2, 11, 24, 35, 44, 45, 60, 61, 69, 75, 85, 87, 118, 126, 143, 149, 153, 161, 173, 175, 178, 193, 206, 213–215, 217.
[31] 102, 147.
[32] See also 78, 126, 175.
[33] 174.

the metal. Furthermore, actual spectrographic analysis[34] and microgas analysis[35] showed that hydrogen and its compounds were by far the dominating gases evolved below 650°C. (1200°F.). Shortly above this temperature, it will be recalled, the solubility of hydrogen in steel sharply increases (refer to Fig. 1) so that hydrogen freed from occlusion is no longer forced to diffuse out of the steel and may dissolve freely in the iron lattice. Evolution at the metal-enamel interface should then decrease as the temperature increases above 600° or 700°C. (1100° to 1300°F.), and this is precisely what it does. Although many blisters burst from the preliminary heavy effusion as the temperature increases, they are actually observed to collapse without breaking, and the boiling ceases.[33] Re-solution of hydrogen into the iron is especially favored by the fact that the enamel coating protectively provides an equilibrium atmosphere of almost pure hydrogen on the face of the metal lattice. Bare metal in time would lose its hydrogen by diffusion into the atmosphere. The ease with which the gas goes back into the metal is attested by the observation that in some cases stock enameled only on one side blisters much less than when enameled on both sides.[36] Blistering by carbon-oxide gases would scarcely conform to any of these observations.

During the remainder of the firing period, the hydrogen is largely in solution in the iron and will remain there until the temperature falls and the functions of diffusibility and solubility reverse to cause the gas once again to precipitate from the iron lattice. In a carbon steel or a steel containing other elements reactive with hydrogen, much of the excess hydrogen conveniently collapses within the steel from four volumes of atomic hydrogen, for example, into one volume of quasi-methane, as has been explained. Other portions of the gas will find their way back into the rifts, inclusions, and grain boundaries from which they originated. An appreciable part will find the metal-enamel interface, of course, and will there diffuse away through the enamel or will create pressures sufficient to rupture the enamel in a type of defect recognized as "fishscaling."

The enameled specimen is now in precisely the same condition with regard to hydrogen as it was before the first firing, except that a portion of the original hydrogen has been lost. Although additional hydrogen is often absorbed by the steel during the first firing, as previously explained, successive firings will progressively remove hydrogen in the foregoing manner; it is also interesting to note that after 20 to 25 heatings reboiling will no longer occur.[37] The analogy in metallurgy is well known.

The replenishment of hydrogen that is provided by reactions of the steel with steam in the furnace atmosphere or with chemically combined moisture in the slip should be quite well understood. To form *one* mol of the black, magnetic iron oxide that may largely constitute the "hazy layer" in enamel[38] and that is thought by some to be related to blistering in cast-iron enameling,[39] *eight* mols of atomic hydrogen are liberated according to the reaction,

$$3Fe + 4H_2O = Fe_3O_4 + 8H.$$

Likewise, the formation of red iron oxide, Fe_2O_3, liberates *six* relative mols of atomic hydrogen. Most important is that the liberation occurs in contact with hot steel, where chances for solution of such nascent hydrogen would be excellent even at low temperatures. It is significant that a great deal of importance has been attached to this oxide-containing "hazy layer," for without it there is poor adherence,[40] and Howe and Fellows[41] record that the more vigorously an enamel boils, the better the adherence. There is no need to believe that the iron oxide results from reduction by the iron of refractory oxides in the enamel when reaction with moisture is so much more feasible, for no matter how carefully the slip is dried, about 1% by weight of moisture will remain[42] until a temperature of about 800°C. (1470°F.) is reached and this combined water is released.[43] In addition to this moisture, steam in the furnace atmosphere is most effective and has often been shown to cause bad blistering[44] even when present only in amounts of 5[45] or 10%,[46] whereas the addition of oxygen to the atmosphere has no effect.[47] Again, irons and steels that blister in ordinary atmospheres will not blister when fired in nitrogen[48] very likely because hydrogen, not oxygen, is absent. Carefully venting the firing furnace is common practice to avoid blistering,[49] which again must be due to the removal of hydrogen and not of oxygen.

The foregoing hypotheses regarding the effect of hydrogen on enamel coatings can be quite easily proved true by simple experiments. All specimens in the following experimental work were prepared by using the standard enameling procedure outlined in discussing Fig. 12 unless otherwise noted. Pickling times varied between 15 and 30 minutes, depending on the requirements of the specimens. Variations in the pickling time, of course, will cause only unimportant quantitative variations in the results.

In the present experiments, ordinary steel, which contains 0.15 to 0.20% carbon, was used instead of the usual low-carbon enameling stock. With a suitable understanding of the functions of hydrogen in steel, it is possible, as will be shown, to disregard moderate carbon contents of the steel and still obtain enamel coatings that are free from the defects under consideration.

(2) Blistering Caused by Hydrogen in Simple Solution

From Figs. 14 and 15, a fair conception may be obtained of the diffusibility of hydrogen that is dissolved

[34] 118. [35] 143. [36] 78, 102, 126, 147.
[37] 102, 126.
[38] 85, 130.
[39] 87, 216.
[40] 126, 138, 175.
[41] 176.
[42] 197.
[43] 118, 161.
[44] 54, 56, 98, 126, 136, 141, 157, 175, 197–199, 215.
[45] 215. [46] 141. [47] 98.
[48] 99, 104, 126, 175.
[49] 10, 126, 141, 175.

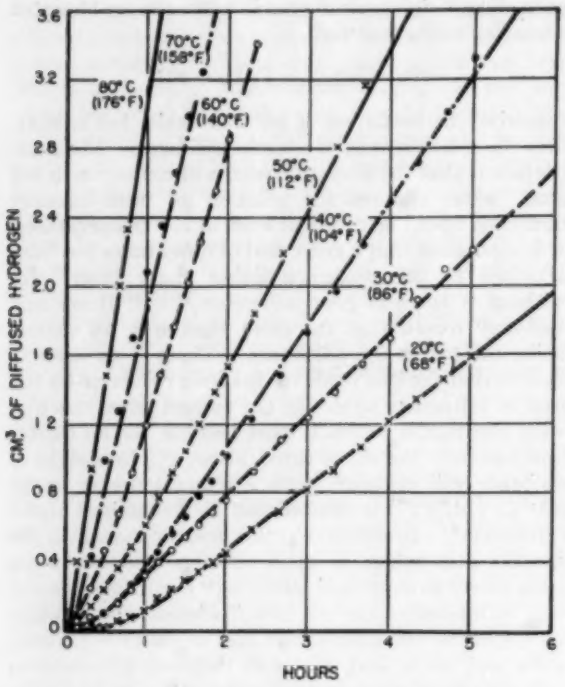

FIG. 14.—Effect of temperature on the diffusion of hydrogen through 9 square inches of 0.05-inch steel sheet (Bardenheuer and Thanheiser). Hydrogen generated by 20% (by volume) H_2SO_4.

in steel. Figure 14[50] shows that as the temperature increases from room temperature to 80°C. (176°F.) the quantity of hydrogen that will diffuse through a given thickness of steel increases about thirty-fold. This conforms with the effusions shown in Figs. 6 and 12. Figure 15[50] shows the marked effect of thickness of the metal section on the diffusion of hydrogen.

To find, experimentally, the time and temperature of drying or aging necessary to eliminate hydrogen held in

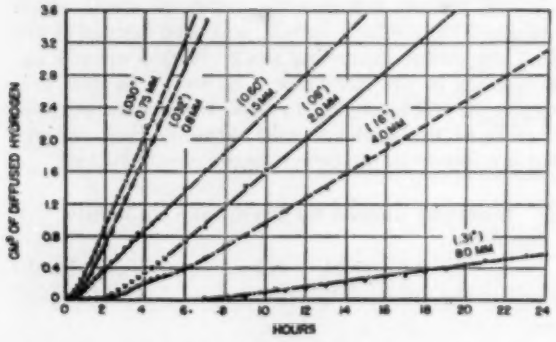

FIG. 15.—Effect of thickness of metal on the diffusion of hydrogen at 25°C. (77°F.) through 9 square inches of steel sheet (Bardenheuer and Thanheiser) Hydrogen generated by 20% (by volume) H_2SO_4.

[50] P. Bardenheuer and G. Thanheiser, "Untersuchungen über das Beizen von Kohlenstoffarmen Fluszstahlblechen," *Mitt. Kaiser-Wilhelm Inst. Eisenforsch. Düsseldorf*, 10, 323–42 (1928).

simple solution in the steel, a rough wedge of plain carbon steel was covered with a blue ground coat and given a total drying period of 30 minutes at 115°C. (240°F.) before firing at 870°C. (1590°F.). The result is shown in Fig. 16.

It is seen that the enamel fused quite smoothly from the thin top down to where the steel was about $^3/_{16}$ inch thick. In thicker sections, the dissolved hydrogen did not have time to leave the steel completely during the

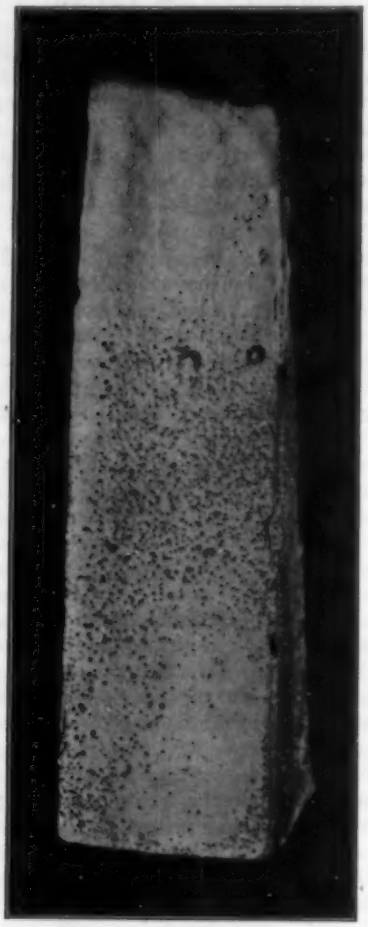

FIG. 16.—Wedge of plain carbon steel fired with blue ground coat 5 minutes at 870°C. (1590°F.) after aging for 30 minutes at 115°C. (240°F.).

aging period of thirty minutes. Of course, the distribution of the blistering may also be attributed to resolution of the hydrogen in the thinner section where the metal had come to temperature, as heavier sections heated more slowly and hence remained longer at temperatures where hydrogen is evolved and not dissolved. Specimens in the present investigation, however, were fired in a furnace that permitted observation of the firing process, and the thin section did not show the boiling that characterized the thicker section.

This one specimen therefore portrays in a new light the "boiling-down" period that must be allowed for obtaining a satisfactory coating. Heretofore the boiling and bubbling have been generally regarded to be a result of chemical reactivity between the iron, particularly carbon in the iron, and the enamel. No explanation has been advanced to account for the fact that the bubbling subsides and will not recur until the specimen is first cooled nearly to room temperature. Numerous investigators have suggested that the gas comes from the metal,[51] and the gaseous evolution has been shown to be quite independent of the coating.[41] Slow heating, furthermore, prevents reboiling.[52] Other observations corroborating the hydrogen theory have already been discussed. Some of the boiling action, of course, is due to the reactivity of iron with moisture, as explained, and that action was observed to be progressing weakly in the tip of the wedge. The strong boiling in thicker sections was due primarily to evolution of hydrogen that had dissolved into the iron during pickling. Regardless of the source in either case, the offending gas is hydrogen, and it is most likely that the tiny bubbles that act to opacify ground coats are also caused by hydrogen.

This wedge further demonstrates the reason why enameling defects, and hydrogen defects in general, bear a strong relation to the microstructure of the steel. A longitudinal section through the wedge would show, of course, a variation in structure corresponding to the variation in temperature and in heating and cooling rates; when steel transforms, the solubility of hydrogen is also markedly altered. The relation, then, of microstructure to enameling defects is often only coincidental.

FIG. 17.—Walnut coating fired 9 minutes at 735°C. (1350°F.) on a $^3/_{16}$-inch steel plate after baking only 5 minutes at 115°C. (240°F.).

The practical result of the experiment showed that hydrogen in simple solution in this steel will not cause blistering in specimens that have no section thicker than $^3/_{16}$ inch if the specimen, after pickling, is aged 30 minutes at 115°C. (240°F.). To demonstrate the severity of the action that may result from this dissolved hydrogen if it is not properly removed from the steel, a $^3/_{16}$-inch plate of ordinary steel was coated with enamel and fired at 735°C. (1350°F.) after only five minutes of baking at 115°C. (240°F.). The result is shown in Fig. 17.

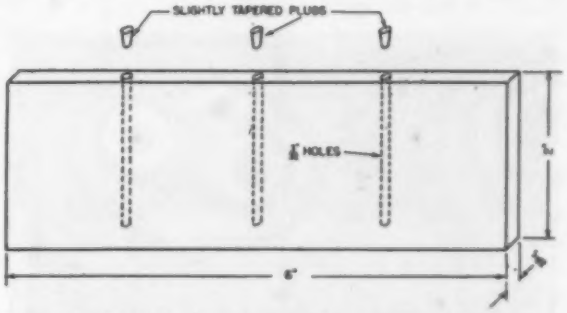

FIG. 18.—Sketch showing specimen of $^3/_{16}$-inch steel plate containing artificial gas-tight cavities.

The hydrogen in these tests, of course, is almost entirely derived from the pickling operation in the cleaning treatment. The severe gas effusion that ruined the coating on the specimen shown in Fig. 17 cannot possibly be due to the carbon-oxide reaction, for the firing temperature was only 735°C. (1350°F.). Note that this firing temperature is so low that very little hydrogen can dissolve in the steel. Correspondingly, the effusion was most severe and did not subside during the 9-minute firing period nor for some days after cooling. The specimen stood at an angle in the furnace, and when the enamel fused, blisters formed that were so large they literally hung from the under side of the piece as large, gas-filled droplets. On both sides of the specimen, parts of the coating were completely removed from the steel during firing, as is evidenced by the visibly oxidized areas shown in the figure; and, as the piece cooled, other large pieces of enamel were exploded away by hydrogen that continued to evolve. As may be seen in the figure, the evolution of hydrogen was so severe during firing that no oxidation and no bonding occurred.

An identical plate was similarly treated, except that it was baked at 115°C. (240°F.) for 35 minutes. A flawless coating was obtained.

(3) Blistering Caused by Hydrogen Occluded in Cavities

Commonly used enameling stock is so much thinner than the plate used in this research that hydrogen dissolved in the steel is quite completely removed during the ordinary drying and baking periods. More elusive is the function of those portions of hydrogen that are withheld by cavities or by impurities in the steel. To identify separately the defects caused by hydrogen occluded at cavities or discontinuities within the steel, a plate similar to the previous specimen was drilled with three narrow holes as shown in Fig. 18. Small plugs were driven into the holes and the projecting ends were welded in with a torch. The wall thickness directly over the holes was $^1/_{32}$ inch.

[51] 2, 3, 13, 20, 25, 27, 28, 37, 48, 60, 72, 87, 96, 103, 114, 120, 125, 149, 181, 194, 205, 216, 218, 219.
[52] 78, 105.

According to theories previously discussed, hydrogen absorbed by the steel during pickling will diffuse through the steel, and a portion of this hydrogen will precipitate in internal cavities because the partial pressure of atomic hydrogen in these cavities is zero. Molecular hydrogen will form immediately within the cavity, and

FIG. 19.—Front and back views of enameled plate (Fig. 18), showing severe blistering in ground coat due to hydrogen occluded in artificial cavities.

because hydrogen dissolves only atomically, such trapped hydrogen will remain in the cavities until the steel is heated to a temperature at which the gas molecules freely dissociate in contact with steel. As enamel-firing temperatures are generally high enough to provide such dissociation, enameling a specimen of the type shown in Fig. 18 should bring a train of defects, preferentially located directly over the cavities.

The specimen was therefore treated in the standard manner (pickling time, 25 minutes) and was baked at 115°C. (240°F.) for one and one-half hours to insure riddance of all dissolved hydrogen. Occluded hydrogen, of course, would remain in the steel. Fired with blue ground coat at 870°C. (1590°F.), the specimen is shown in Fig. 19.

Expectations were more than fulfilled, for the effusion of gas directly over the three cavities was so severe that the enamel in one instance was completely removed. A second firing showed no substantial decrease in the effusion, nor did a third firing.[53] The specimen was then sprayed with a white cover coat and fired four minutes at 810°C. (1490°F.). The result is shown in Fig. 20.

In spite of the fact that the specimen had been successively fired three times at 870°C. (1590°F.), a total time of fourteen minutes at that temperature, the gas continued to effuse so violently while firing the cover coat that blisters raised corresponding to the entire length of each cavity; and, as the specimen cooled, the hydrogen that had dissolved in the thin steel wall precipitated in such quantities that pressure developed, although counteracted by greatly decreased temperature, sufficient to explode several large blisters and to throw two of the largest several feet from the specimen. In the exposed areas under these two blisters, the ground coat is visible, and blisters in the ground coat in turn expose the steel. Note the marked difference in size of the blisters in ground and cover coats, as this difference explains many observations that have been made regarding the effect of enamel composition on the tendency to show these defects.[54] Permeability and viscosity are obviously strong factors to consider in composing enamels that fire properly, but defects caused by hydrogen can only be mitigated, not corrected, by manipulation of the enamel composition.

To prove that the blistering in the present case was due to gas occluded in the cavities and not to overfiring caused by the rapid heating of the thin metal wall at these loci, two more identical plates were drilled in the same way but the holes were left open so that hydrogen could not be occluded. Both were fired with blue ground coat. One was then purposely overfired until burning occurred, but the burning bore no relation to the cavities, as may be seen in Fig. 21. The other plate was fired with white cover coat. Ground and cover coats on this specimen are shown in Fig. 22, and it is seen that there is no surface demarcation whatsoever to indicate where the holes lie.

To prove that the occluded gas responsible for the blistering under discussion was hydrogen and not merely air or other gases trapped during preparation of the cavities, an identical plate with sealed holes was

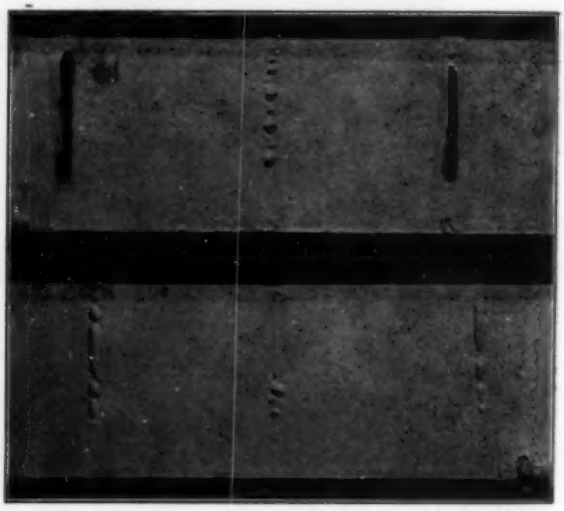

FIG. 20.—Front and back views of specimen (Fig. 18), fired 4 minutes at 810°C. (1490°F.) with white cover coat.

cleaned by sandblasting instead of by pickling. Fired with both blue ground and white cover coats, the specimen showed no defects whatsoever. One should not expect entrapped air, if dry, to cause surface defects because both oxygen and nitrogen react with iron at

[53] It is hoped that the reader will appreciate that the specimens photographed in this research were prepared by metallurgists, not enamelers, and that numerous mechanical defacements have accordingly occurred that might have been avoided with better technique. Such mechanical defacements, however, are inconsequential to the thesis.

[54] 96, 126, 175.

enamel-firing temperatures to form solid phases. It should be pointed out that the use of sandblasting instead of pickling, although successful in this test, cannot be depended upon for strict riddance of hydrogen-caused defects for reasons already explained. In the present case, it was known that hydrogen was not present in the discontinuity in the beginning of the test.

FIG. 21.—Test plate with holes unsealed, purposely overfired to show that blistering in previous figures was not caused by rapid heating of thin metal over cavities.

These tests clearly illustrate the reason that enamel defects are often found overlying blowholes, pipe, porous metal, and inclusions,[55] in fact any heterogeneity that is sealed within the steel but near enough to the surface to be effective. Defects in the steel that open onto the surface do not cause blistering[56] unless liquids become entrapped in them because the defect is an open hole and cannot trap hydrogen.

(4) Effect of Inclusions in Steel

An inclusion in steel, of course, is a discontinuity and may act exactly and solely as a cavity in which molecular hydrogen may precipitate. It has been shown

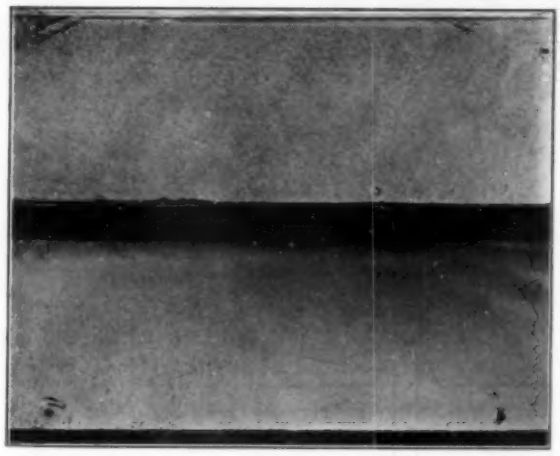

FIG. 22.—Ground coat (above) and cover coat (below) fired on a plate containing open holes; coatings show no evidence of underlying cavities.

by experiment that the hydrogen atoms recombine so instantaneously upon leaving the metal lattice that it is often difficult to obtain a chemical reaction with other elements. Nevertheless, if there is good contact, reactions are especially favored, particularly with oxygen, and the resulting hydrogen-containing products naturally respond to temperature changes differently than does molecular hydrogen. The greatest difficulty in identifying defects as hydrogen functions has perhaps resulted from these retentive chemical actions of unknown impurities in the steel. As a result of these complicating reactions, hydrogen may be released at almost any temperature, depending both on the physical and the chemical nature of the many components that differentiate steel from iron.

In an attempt to demonstrate some of the anomalous effects produced by impurities in steel, three types of test were performed in the present research in which the retaining conditions were physically and chemically different. First, artificial and lightly packed impurities with poor metallic contact were studied. The three holes in a customary test plate were arranged as follows: (1) sealed empty, (2) tamped full of graphite and sealed, and (3) tamped full of iron oxide (red rouge) and sealed.

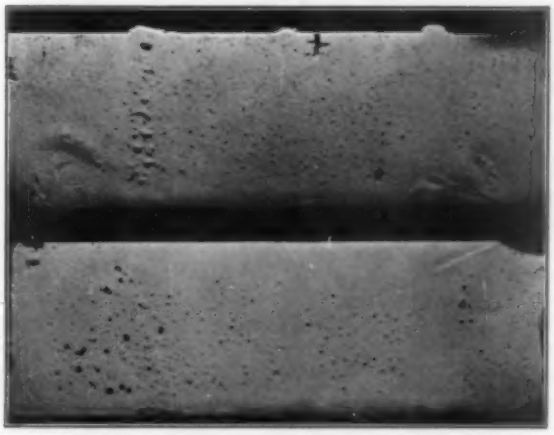

FIG. 23.—Plate with three sealed holes containing iron oxide, graphite, and air, respectively; cover coat shows distribution (after firing) of hydrogen absorbed during pickling.

The plate was prepared in the usual manner so that hydrogen from pickling would precipitate in the three cavities. Firing a blue ground coat showed no trace at all of the underlying cavities. The piece was re-fired twice without renewing application of the slip, but no evidence of hydrogen defects appeared, in sharp contrast to the specimen shown in the previous figures. A white cover coat was then applied, and firing brought the results shown in Fig. 23.

The specimen had been lightly pickled purposely to favor differentiation of any effects imposed by the enclosed impurities on hydrogen re-solution during firing. As a result, the molecular hydrogen in the right-hand hole has been completely dispersed by the several firings so that the best surface on the whole plate is that which directly overlies this third hole. That area corre-

[55] 3, 13, 27, 57, 60, 85, 87, 103, 114, 120, 149, 181, 192, 194, 216, 219.
[56] 216.

sponded to the thin section of the wedge in Fig. 16 after the occluded hydrogen had been removed, and it is significant that the hydrogen occluded during this shorter pickling period was insufficient to blister the ground coat. Furthermore, the distance that the hydrogen has diffused through the length of the plate after leaving the cavity is evidenced by the blisters that occur at either side of the hole. Defects on the surface have thus completely reversed their characteristics around this cavity. The thinnest metal section was the most immediate exit for trapped hydrogen and became in turn the first section to be free of the gas and therefore the first to "boil down." The thicker sections received the laterally diffusing gas, and the train of blisters marks its progress.

The central cavity, which contains graphite, evidences a slightly less advanced stage of hydrogen removal. This should be expected because hydrocarbons would form but would be largely dissociated at the firing temperature. Hydrocarbon that dissociated in direct contact with the iron may have provided immediate escape for the nascent hydrogen, but in such a large, lightly packed mass, it is more likely that molecular hydrogen resulted from the decomposition. The gas would then behave much as that in the right-hand cavity except that re-solution would be slightly retarded by remanent carbon-hydrogen bonds. The evidence shown in Fig. 23 supports this reasoning.

The left-hand hole, which contained red iron oxide, is sharply delimited on the surface with blisters and shows that hydrogen has been strongly retained, most likely by reaction with the oxide to form water vapor. The wide dispersion of small blisters attests that some gas escaped during the first firing just as it did from the other holes, so it must be assumed that molecular hydrogen was also present and that dissociation (in contact with iron) of water vapor above 800°C. (1470°F.) is slower than the dissociation of molecular hydrogen. Alternatively, dissociation of the water vapor to reproduce iron oxide must deposit this iron oxide, of course, on the metal surface where the reaction occurs and would thereby form a layer that would retard further reaction until the necessary diffusion had occurred.

The curious lack of blistering in the ground coat of this specimen is significant in regard to the little-understood relation of cover-coat blisters to ground-coat behavior.[57] That the gas evolved continuously since the first heating is clearly indicated by the dispersion of blisters just discussed. There is evidently a great difference in refractoriness, viscosity, and permeability to hydrogen between the ground and cover coats. The marked permeability of this particular ground coat to hydrogen perhaps explains why some investigators have claimed that blistering can be eliminated by manipulating properly the composition of the enamel[58] and that the length of the pickling period often affects blistering.[59] It may also explain why some persons have supposed that blisters in a cover coat are caused by reaction with the ground coat[60] and that "reboiling" is not related to "primary boiling."[61] This does not mean that reboiling is always just a repetition of the primary boil, for in many instances the steel is initially free of critical amounts of hydrogen and becomes "loaded" for the first time when chemically combined water in the enamel of the first coat or hydrogen-containing furnace gases react with the iron. Further discussion of reboiling will be reserved until later.

The contrast of blistering activity in the test just discussed is interesting for if a certain "fraction" of hydrogen-retaining impurity predominates in a dirty steel, an enamel may be satisfactorily used whose firing temperature is not the temperature at which the impurity releases its hydrogen. This selective effect of impurities is even better illustrated in the following experiments.

It was stated that good contact of the impurity in an inclusion with the atomic hydrogen at the instant that the gas leaves the metal lattice is important for reaction. As the test just discussed plainly lacks good contact of impurity with metal, a second group of tests was made wherein the artificially introduced inclusions were hot-worked into the steel, thereby more closely simulating natural conditions. In the first tests of this

[57] 97.
[58] 96, 126, 175.
[59] 59, 96, 190, 193, 219.
[60] 101. [61] 126.

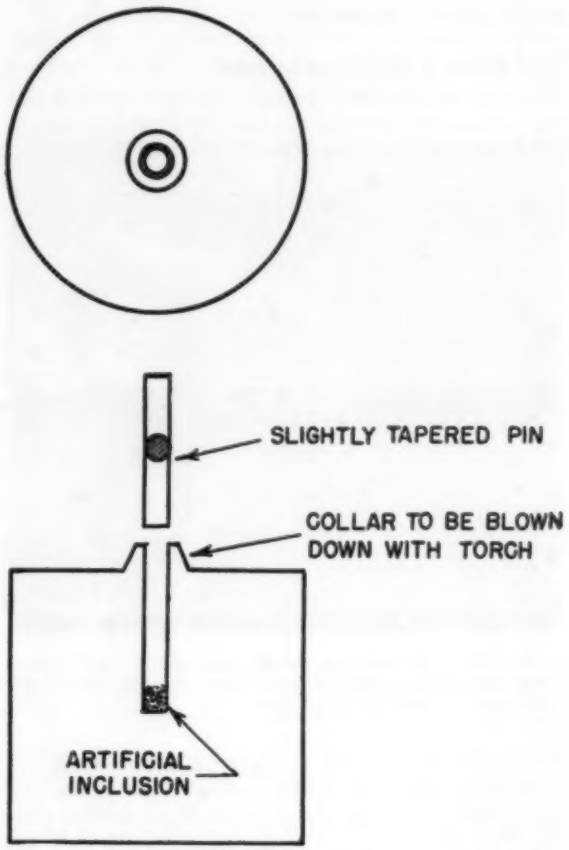

FIG. 24(*A*).— Sketch showing method of introducing inclusions into steel.

group, an ordinary 2-inch round steel bar was cut into four 2-inch lengths and these were drilled as sketched in Fig. 24(*A*). In the four specimens were placed 0.1-gram samples, respectively, of the following impurities:

(1) Natural tephroite $(MnO)_2 SiO_2$
(2) Synthetic fayalite $(FeO)_2 SiO_2$
(3) Open-hearth slag with an analysis of

	(%)		(%)
FeO	24.9	MgO	7.8
Fe_2O_3	11	MnO	6.6
SiO_2	9.5	P_2O_5	1.3
Al_2O_3	1.6		
CaO	35.9	Total	98.6

(4) FeS mixed equally with MnO_2.

Small quantities were used to simulate natural conditions. Before inserting the powders, the holes were cleaned with dilute sulfuric acid, washed with distilled water, rinsed with dilute sodium carbonate solution, and dried with acetone. Tapered pins made from the same steel were treated similarly. After inserting the powders, the pins were peened, and the steel flange was welded over with a torch. No welding rod was used. The pieces were immediately placed in a furnace at 1300°C. (2370°F.), annealed for one hour, and were forged as shown in Fig. 24(*B*). After shearing the nubbins, the plates were heated in a furnace to 1100°C. (2010°F.) and were rolled in two passes to about 0.10 inch in thickness. They were then clipped to a smaller size, as the location of the inclusions could be roughly predicted.

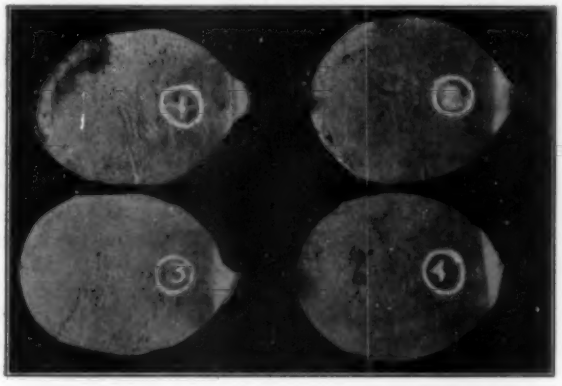

FIG. 24(*B*).— Pieces after forging.

The plates were pickled for 25 minutes to insure obtaining the severe hydrogen conditions that characterized the specimen in Fig. 19. The four sheets were fired at 870°C. (1590°F.) with blue ground coat, but no defects whatever appeared. Plate No. 3 was fired twice for a total period of 15 minutes, but no defects became visible. Plate No. 1 was reheated to 600°C. (1100°F.) in an unsuccessful attempt to develop fishscaling and was then further heated to 1050°C. (1900°F.) where the enamel burned badly but did not reveal where the inclusion might lie.

All four plates were deenameled in sulfuric acid and pickled until blisters arose over each inclusion (see Fig. 26). Comparing Fig. 25 with plate No. 1 in Fig. 26, it was evident that the location of the inclusion was not revealed by firings at 600°, 870°, and 1050°C. (1100°, 1600°, and 1900°F.). The poor appearance of blistering in plate No. 4 is undoubtedly due to depletion of the impurity by reaction of the oxide and sulfide to form a partially diffusible gas. Except for this one semisulfide inclusion, the impurities are predominantly oxides, and there are indications that these oxides have effectively restrained hydrogen from appearing in deleterious quantities during firing. Of course, the permeability of this ground coat was demonstrated in a previous test,

FIG. 25.—Plate (1) (Fig. 24 *B*) overfired with blue ground coat at 1050°C. (1920°F.).

and, as in Fig. 23, a denser coating might well blister also in the present test. Nevertheless, the ground coat and the pickling period were the same as in the test shown in Fig. 19, and yet no blistering has occurred. Figure 26 shows that all of the inclusions were in gas-tight pockets and that they occluded hydrogen during pickling.

Another test of the hot-rolled impurity type was made wherein the three holes in a customary plate were filled with silica and sealed, much as in the specimen shown in Fig. 23. The plate was heated to 1175°C. (2150°F.) and was reduced 50% in two passes through the rolls. Firing blue ground coat on this

specimen also failed to show any surface evidence of the underlying cavities and impurities.

An effect of impurities in steel on hydrogen retention has been shown for the two cases of (1) porous metal with loosely packed impurities and (2) forged and rolled inclusions. The third and last case involves the effect of carbon in steel on enameling defects and will be considered separately and at length because it is apparent from the literature that a satisfactory understanding of the relation has not yet been reached.

(5) Effect of Carbon in Steel

It is not surprising that shop observations on blistering and boiling effects have been interpreted as results of carbon-oxygen reactions rather than primarily as hydrogen functions, for carbon and hydrogen are so

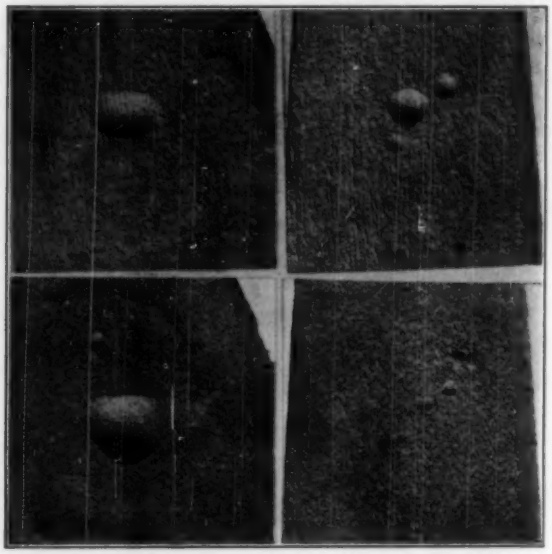

FIG. 26.—Hydrogen blisters at seats of artificially introduced inclusions; (*top left*) plate (1); (*top right*) plate (2); (*bottom left*) plate (3); (*bottom right*) plate (4).

closely associated in steel that it is most difficult to disentangle their individual activities. It must be admitted that carbon will reduce oxides in the enamel to some extent during firing and that the oxidizing action of steam must oxidize some carbon in the iron as well as the iron. The preponderance of hydrogen, however, theoretically liberated by these reactions and found by spectrographic[62] and by microgas analysis[63] suggests that carbon-oxide gases may not deserve the position of major importance granted them by recent writers in this country.[64] It is interesting that as early as 1912[65] one investigator decided that blisters were due to gases in the steel and "also" to gases resulting from the reduction of oxides in the enamel by carbon in the steel.

[62] 118, 143, 161.
[63] 143.
[64] 126, 143, 149, 153, 161, 173, 175, 178, 193, 206, 213, 215, 217.
[65] 2.

In the carbon-oxide theory, no account is taken of hydrogen. The argument further weakens when it is shown that steel with 0.01 carbon reboils as badly as 0.12 carbon steel[66] and that reboiling not only depends on the atmosphere of the furnace but that gases containing hydrogen, viz., CH_4, H_2O, H_2S, NH_3, H_2, and commercial fuel gases, cause severe blistering[67]; whereas the addition of oxygen to coal gas stops blistering,[67] and oxygen added to a normal atmosphere has no effect on blistering.[68] If a piece is fired in nitrogen or in a vacuum, reboiling will not occur during the subsequent firing even if fired in air, but if the procedure is reversed, reboiling will occur[69]; and if the specimen is slowly cooled after firing in any atmosphere, reboiling will not occur.[70] The "loading" of the piece with hydrogen during the initial firing is obvious, but published opinion usually holds that reboiling is in no way concerned with the initial firing[71] and that carbon-oxygen reactions are the cause of blistering phenomena.

There are many miscellaneous observations in the literature on reboiling and blistering that stand unexplained, or wrongly explained, which may be explained as functions of hydrogen. The discrepancies in observations reported on the effect of thickness of the specimen on reboiling[72] may be correlated by proper consideration of the time and temperature relations that control diffusion of hydrogen during and after pickling, as the gas diffuses slowly throughout the specimen, and during firing when the solubility increases so markedly. Given a certain pickling period, thin specimens may largely lose their dissolved hydrogen to the atmosphere during a given aging period. Thicker specimens, however, will disperse their hydrogen within as well as without during aging, which may prevent reboiling or may aggravate it, depending on the amount of hydrogen absorbed, the relative volume of the metal, and the increase in solubility during firing.

Scott[73] enameled copper without trouble, but copper-coated iron blistered unless the piece was slowly heated to the firing temperature. Carbon cannot operate in this case, and slow heating is the well-known panacea for hydrogen troubles. Howe[74] shows that a scratch on the metal will result in blisters in the enamel. In metallurgy, it has been demonstrated that hydrogen is most rapidly absorbed at scratches and cold-worked surfaces and that the gas occludes in submicroscopic rifts in great quantities.

(6) Defects in Enamel Coatings on Cast Iron

Cast irons were not enameled in this work, but there is reason to believe that similar defects[75] have similar causes and that, in enameling cast iron, hydrogen

[66] 161. [67] 56. [68] 98.
[69] 53, 54, 56, 99, 102, 104, 110, 126, 136, 141, 157, 161, 175, 218.
[70] 102, 110, 131.
[71] 147.
[72] 110, 175.
[73] 105. [74] 211.
[75] 17, 18, 20, 23–25, 28, 35, 44, 45, 51, 52, 55, 58, 60, 61, 69, 75, 77, 79, 87, 98, 99, 104, 114, 120, 125, 126, 128, 133, 149, 153, 155, 159, 175, 178, 181, 194, 205, 206, 209, 213–216, 218.

again has been overlooked in favor of carbon-oxygen reactions. For example, Dennery[76] finds that castings enamel with less blistering if they have been shaken out cold from the mold rather than hot. Spencer-Strong[77] slow-cooled one of three identical castings and found that only the slow-cooled casting enameled without blistering. Delcroissette,[78] discussing the work of Emmel,[79] observes that repeated heatings of castings to not over 100°C. for a period of several years makes the castings enamelable without blistering. These observations on the beneficial effects of aging and slow cooling are identical with those already discussed in regard to (1) ridding a steel of "flakes," "shatter cracks," and similar hydrogen-caused defects and (2) avoiding reboiling in sheet-steel enameling. The usually accepted explanation in the literature, however, is that rapid cooling causes a thin layer of white iron to be retained on the surface of the casting and that this layer of "microchill" contains carbon that is peculiarly amenable to reaction with oxides in the enamel or with oxygen in the air.[80] The effects of furnace atmosphere[81] on blistering, however, are identical with those observed for reboiling on sheet steel. No blistering occurs if the casting is fired in nitrogen,[82] but blisters appear if fired in air, especially when steam is present, and the blistering becomes worse if the weather is damp.[83] The beneficial effect of nitrogen, therefore, may be due principally to the fact that water vapor is largely excluded from the atmosphere and, therefore, the evolution of hydrogen is minimized. Poste[84] reports that a good cast iron, when heated in air, gives off more CO_2 than a bad cast iron, and a patent has been granted for firing in nitrogen or *carbon dioxide* atmosphere to *prevent* blistering.[85] Schulze[86] relates defects in the iron to defects in enamel just as has been done in the case of sheet steel. Spencer-Strong[77] apparently shows that black magnetic oxide scattered through the casting, particularly as small inclusions, is responsible for blistering, but that if the inclusion is near the surface no blistering results. The micrographs he presents for nonblistering inclusions show that these inclusions open to the surface, and the observation is thereby explained by the present research. The reaction by which black magnetic oxide is produced has already been discussed. A simple calculation shows that each volume of Fe_3O_4 produced by a reaction of iron with moisture is accompanied by an evolution of *nearly 4000 volumes of atomic hydrogen* measured under standard conditions. This enormous figure approaches *15,000 volumes of atomic gas per volume of black magnetic oxide* when measured at enamel-firing temperatures. Is it surprising that blistering is so closely associated with Fe_3O_4 particles in cast iron and with adherence and oxide layers[87] in sheet-steel enameling?

Most corroborative of the importance of hydrogen in causing defects in cast-iron enameling are observations regarding the effects of processing.[88] Poste[89] and Wolfram[90] found that blistering developed in irons made with additions of scrap and that blistering did not occur if no scrap had been added. In metallurgy, exactly the same observation has been made for hydrogen defects, and it has been shown that the rust on scrap, if only 1% of the weight of the bath, provides about 20 relative volumes of hydrogen to the melt. Poste also notes that heavier castings blister more than light ones. In metallurgy, thick sections are notably more susceptible to hydrogen defects, principally because the greater thickness of metal frustrates removal of the gas. Manson[91] traces the cause of blistering to the foundry and suggests the use of a higher percentage of remelt and that more attention be given to the production of the iron. Some investigators have suspected that blistering is caused by gas absorbed from the blast furnace,[92] and some believe that the malefic element escapes ordinary analysis.[93] Cowan[94] points out that carbon accounts for 10% of the volume of cast iron and that it is unreasonable to postulate local chemical reactions. Poste[95] and Andrews[96] show that the total amount of carbon-oxide gases evolved at enamel-firing temperatures is unrelated to blistering, and they suggest ".....that minute amounts (of carbon oxides) at certain critical periods which have escaped detection by the methods employed may be responsible for blistering." Spencer-Strong[77] calls attention to the contradictions in the carbon-oxide theory and argues that other gases must be responsible. English literature contains no suggestion as to what that other gas may be.

In spite of these reasons, and many others, for suspecting hydrogen as the primary cause of blistering in cast iron, the most widely accepted theory, as has been mentioned, is that the combined carbon in the thin surface layer of the casting breaks down during firing and produces graphite of such fine division and high chemical energy that reaction with oxides proceeds. It has been shown, however, that blistering will not occur if the piece is fired in nitrogen, so it cannot be the reduction of oxides in the enamel that produces carbon-oxide gas; it has also been shown that firing in a reducing atmosphere that contains hydrogen causes severe blistering, so it cannot be a reaction with oxygen in the furnace atmosphere that causes blistering. Furthermore, pearlitic structure is advised in cast iron[97] and advised against in sheet steel to avoid blistering. An obvious conclusion to draw is that hydrogen is an important gas in producing blisters in iron and steel enameling, and, although other reactions may also cause blistering, they are probably secondary in importance.

In metallurgy, it has been shown that hydrogen acts strongly to retain cementite in cast iron, so the layer of microchill that results from casting in a wet mold may

[76] 206. [77] 216. [78] 205. [79] 209.
[80] 24, 35, 44, 45, 60, 61, 69, 75, 87, 149, 153, 178, 206.
[81] 98, 99, 104, 215.
[82] 99, 104.
[83] 17, 133, 214.
[84] 104. [85] 148. [86] 120.
[87] 16, 138, 146, 176.
[88] 25, 28, 60, 79, 87, 104, 114, 120, 125, 149, 181, 194, 206, 213, 216.
[89] 87. [90] 125. [91] 181.
[92] 25, 28.
[93] 20, 25, 28, 194, 216.
[94] 194. [95] 104. [96] 126.
[97] 69. [98] 178.

be due to hydrogen, as suggested by Howe and Manson.[98] White iron has also been shown by direct analysis to have a high hydrogen content,[99] so the significant point about the surface layer may well be that hydrogen is liberated when the layer decomposes. One investigator suggested such a mechanism[100] long ago. Hydrogen need not come from the mold, however, to be present in this layer because rapid cooling of the surface in any manner will frustrate the removal of the hydrogen inherited from melting.

(7) Differentiating Effects of Hydrogen and Carbon by Experiment

The strong attraction between carbon and hydrogen has caused misinterpretation of the mechanism that leads to blistering because carbon is the only visible component. Of course, when hydrogen enters the metal from reactions of iron with moisture during firing,

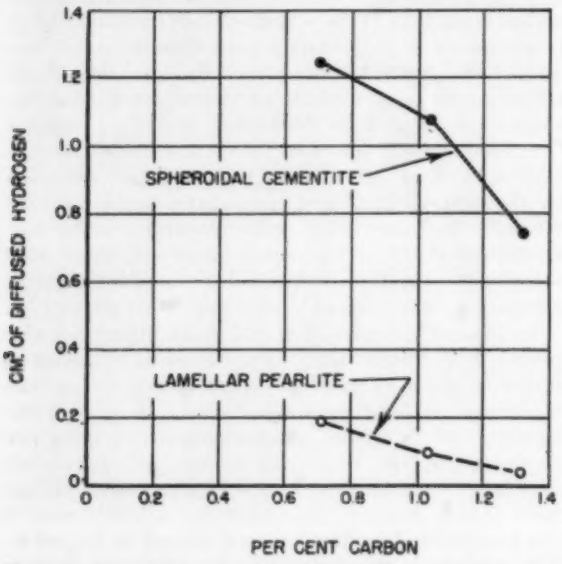

FIG. 27.—Effect of content and condition of carbon on the diffusion of hydrogen through 9 square inches of 0.05-inch steel sheet at 40°C. (104°F.) (Bardenheuer and Thanheiser). Hydrogen generated by 20% (by volume) H_2SO_4.

the oxide evident on the surface and in the under layer of the enamel provides indirect evidence of hydrogen absorption that has not been sufficiently recognized.

It might be pointed out that segregations of pearlite, which have been observed to cause blistering,[101] also imply segregation of hydrogen in interstices and in the pearlite; and during pickling and cooling after firing, these regions will be especially enriched with hydrogen. Surface segregations may well cause the formation of carbon oxides, but often the segregations lie beneath the surface where carbon-oxygen reactions could not possibly be effective.

[99] H. A. Schwartz and G. M. Guiler, "Hydrogen in Solid White Cast Iron," *Trans. Amer. Foundrymen's Assn.*, Preprint No. 39–4, 7 pp. (1939).
[100] 75. [101] 85.

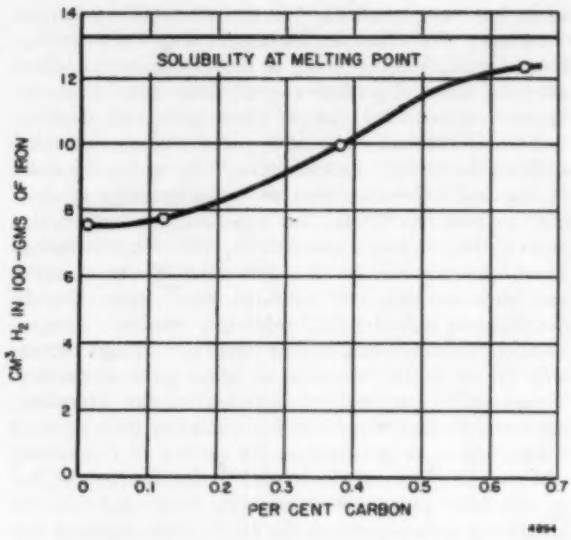

FIG. 28.—Effect of carbon on retention of hydrogen in cast steel (Bardenheuer and Keller).

The strong effect of pearlite on the retention of hydrogen is shown in Fig. 27,* and it is seen that, for a given carbon content, the diffusibility of hydrogen in steel is increased more than tenfold by a spheroidizing treatment and that, as carbon increases in any form, the diffusion of hydrogen decreases. Experimental analyses of the hydrogen content of various cast steels a certain period of time after casting are plotted in Fig. 28,[102] and as the carbon increases, the residual hydrogen in the steel increases. At the melting point of iron, 1528°C., the solubility of hydrogen under one atmosphere pressure is 13.3 cu. cm. per 100 grams of iron, and 0.6% carbon is shown to cause retention of nearly that quantity.

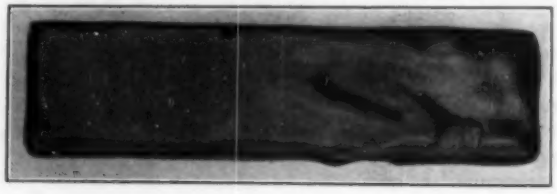

FIG. 29.—Blue ground coat fired on piece of graphite; (*left*) light application; (*right*) uneven heavy application.

A plate of pure graphite was enameled in the present research in an attempt to find the extent of carbon-enamel reactivity. Firing a blue ground coat did not result in blistering. The bar was given a heavy, uneven second coating on one end and fired again, but still no blistering occurred (Fig. 29). Of course, the porosity

* See footnote 49, p. 197.
[102] P. Bardenheuer and H. Keller, "Über den Einflusz des beim Schmelzen aufgenommenen Wasserstoffs auf den Stahl," *Mitt. Kaiser-Wilhelm Inst. Eisenforsch. Düsseldorf*, **18**, 227–37 (1936).

of the graphite may have prevented the development of sufficient pressure to form blisters, but a surprisingly solid coating was obtained, and there was no noticeable boiling action during firing.

The strong attraction of pearlite for hydrogen, even in the absence of porosity, is shown by the following experiment. Two customary plates, without holes, were carburized by heating with carburizing compound at 950°C. (1750°F.) for fifteen hours, thereby obtaining a high-carbon case approximately 0.03 inch thick. This case was completely ground away except for the rim and two rectangular areas across the width of the plate (Fig. 30). One plate was sandblasted, and the other received the usual pickling treatment. Both plates were given an extended baking period to insure removal of all ordinarily dissolved hydrogen and were then fired with blue ground coat at 870°C. (1590°F.). The results are shown in Fig. 30.

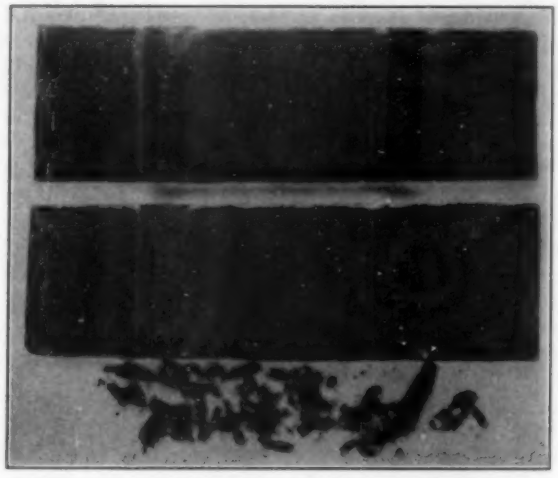

FIG. 30.—Carburized ridges on steel plates fired with blue ground coat; (*upper*) sandblasted; (*lower*) pickled.

The pickled specimen has ostensibly boiled much more violently than the sandblasted specimen. The debris belongs to the pickled plate, most of the chips having come from the sides where the rim is also carbon-rich. It must be recognized that substitution of sandblasting for pickling does not preclude the presence of hydrogen in the sandblasted specimen. A considerable quantity of hydrogen can be absorbed from the reducing gases in the furnace atmosphere and from miscellaneous moisture associated with carburizing, so that a comparison of boiling due to hydrogen in these two specimens can only be one of degree. Correspondingly, it is evident that the specimen prepared by sandblasting has boiled to some extent. Microsections through the carburized ridge of the badly blistered, pickled specimen are shown in Fig. 31. Note the relatively high carbon content of the steel that was used in the present research.

A similar test discussed later in regard to fishscaling develops the same evidence.

An interesting observation during firing was that a tiny brilliant spark marked the combustion of the bubble-forming gas as each blister ruptured. These minute bursts of flame occurred over the bubbles on both specimens, though less frequently on the sandblasted specimen. The gas was not analyzed, but both CO and H_2 burn with blue flames. Methane, however, burns with a luminescent flame, and the firing temperature is well within the range in which hydrogen decarburizes steel. This observation tends to strengthen

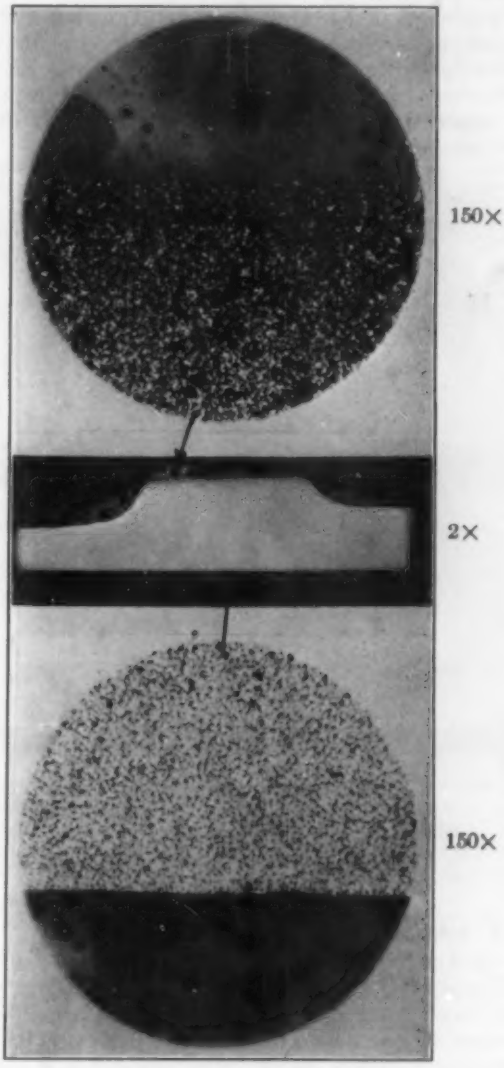

FIG. 31.—Microsections through carburized ridge of sandblasted specimen in Fig. 30.

the argument that boiling is largely due to hydrogen and also suggests that the decarburization, often noted in surface layers of the steel, is due to hydrogen rather than to oxygen.

Hydrogen released into steel by destruction of the C–H bond is illustrated in another test. The three holes in a customary plate were carefully cleaned with distilled water and acetone, and traces of hydrocarbon were removed by firing. A very thin film of ordinary

machine oil was brushed only into the two end holes with a pipe cleaner. The three holes were sealed and welded as before, and the plates were prepared for enameling by sandblasting. Fired with both ground and cover coats, the plate is shown in Fig. 32. The film of oil in the two end holes has decomposed during the heating to release hydrogen and carbon to the steel. As the carbon could not have possibly diffused to the surface during the brief firing period, it can only be concluded that hydrogen, which diffuses much more rapidly than carbon in steel, has caused both primary boiling and reboiling ("blistering in the cover coat") in this specimen. The experiment may serve to explain the observation that a paint mark on enameling sheet will cause reboiling on the opposite side.[103]

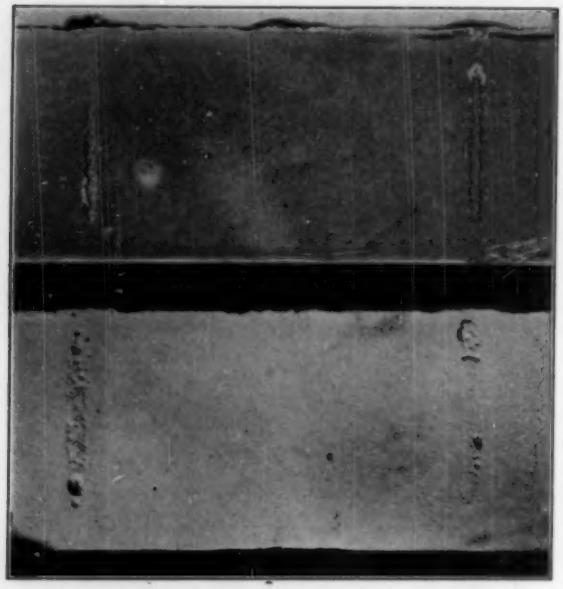

FIG. 32.—Ground (*above*) and cover coat (*below*), fired on sandblasted plate. Two end holes contain thin film of oil which has released hydrogen during firing. Center hole is empty.

(B) Fishscaling

(1) Introduction

"Fishscaling" has been discussed at great length in the enameling literature. As nearly one hundred articles have appeared on the subject of fishscales,[104] it is unnecessary to define the defect or to discuss its appearance. In this country, the accepted explanation given for fishscaling is that the defect is due to mechanical stresses inaugurated by differences in the coefficients of expansion between the enamel and the steel.[105] Some foreign investigators, however, have recognized that fishscaling is caused by the effusion of hydrogen from the steel.[106] Hydrogen at one time or another as a cause of fishscaling has been suggested by writers in this country,[107] but the functions of this gas in steel were almost completely unknown, and all of the suggestions have been discarded. Sweely,[107] in 1922, and Andrews,[108] in 1931, performed the identical type of experiment shown in Fig. 9 of the present work without noting that the enamel chips that exploded off the other side of the acid-treated steel were due to hydrogen. Sweely briefly considered hydrogen, but chose mechanical stress instead as the cause of the chipping; and Andrews suggested that mechanical stresses were inaugurated or became unbalanced by corrosion of the metal in the acid. Shaw,[109] in 1920, suggested that fishscaling was caused by gas that collected under the enamel, and porous enamels that will allow gases to escape during firing have been suggested.[110]

As with blistering and boiling, it has been observed that reducing gases in the furnace atmosphere[111] and overpickling[112] lead to fishscaling, that fishscales are related to defects in the steel,[113] that slow cooling will prevent fishscaling,[114] that the defect is common over weld metal,[115] and that the thicker the "hazy layer" of iron oxide the greater is the tendency to fishscale.[116] The fact that heavy-gauge stock fishscales more than light[117] conforms perfectly with the hydrogen theory but has provided circumstantial and misleading evidence in favor of the mechanical stress theory. Schaal and Fuller[118] state that gas evolves from the metal, and they believe that primary boiling, copperheading, fishscaling, and reboiling are all directly related. Again they show[119] that fishscales are situated over ground coat that has been made spongy by gas evolution during firing. Lastly, studies of expansion coefficients[120] have been unenlightening for there is very little difference between the coefficients for ground-coat enamels and for steel except at the transformation temperature of the steel, and then the enamel is viscous and will not support stress.

Vielhaber,[121] in 1930, was apparently the first to suggest that hydrogen was responsible for fishscaling. Two years later[122] he reported doing the enameled-pan experiment (Fig. 9, present research, p. 192) and recognized that the chipping and scaling were due to hydrogen that had diffused through the steel from the acid reaction on the other side. To give the gas a chance to escape and thereby to prevent fishscaling, Vielhaber suggested that the piece be slowly fired or that a mill addition be made that would extend the range of fusibility of the enamel. Leon and Slattenscheck[123] pointed out that hydrogen in roll blisters (refer to Fig. 4, p. 189) and in slag inclusions would tend to warp the steel and thereby to cause stress in the enamel.

[103] 147.

[104] 1, 2, 4, 5–10, 12, 14, 15, 19, 22, 29–34, 36, 38–41, 47, 50, 56, 62, 64, 66, 67, 70–74, 77, 78, 80–86, 89, 92–94, 100, 107, 113, 115–117, 119, 124, 126, 127, 137, 139, 140, 145, 151, 152, 156, 164–166, 170, 172, 175, 179, 182, 185, 186, 189, 192, 197–200, 204, 208, 212, 217–219.

[105] 2, 4, 5, 8, 9, 12, 19, 30, 32, 41, 50, 66, 74, 89, 119, 126, 139, 140, 166, 175.

[106] 64, 84, 92, 107, 124, 164, 186, 189, 197–200, 212, 218, 219.

[107] 12. [108] 66.

[109] 7. [110] 38. [111] 10. [112] 32, 217. [113] 32, 72. [114] 8.

[115] 192. [116] 85. [117] 7, 9, 50. [118] 89. [119] 62.

[120] 80, 82, 139, 140.

[121] 64. [122] 92.

[123] 164.

Hoff and Klärding[124] and Klärding[125] dried enamel slip for ten hours at 110° to 135°C. (230° to 275°F.) and found that nearly 1% of moisture remained. They then proved by direct experiment that this chemically held moisture breaks down during firing to form principally hydrogen, with some carbon dioxide from the carbon in the steel. The hydrogen diffuses into the metal and acts, as already described in this writing, to cause reboiling and fishscaling. These investigators then placed specimens showing fishscaling in a closed flask, and over a period of two weeks collected one cubic centimeter of gas that analyzed nearly pure hydrogen. Kerstan[126] examined half a dozen different types of enameling stocks, ranging from pure iron to copper-bearing steel, and found that each type varies considerably in initial hydrogen content and that each shows a marked increase in hydrogen content after the first firing. For example, one sheet analyzed,

As received H_2 = 0.00022 weight per cent
After firing H_2 = 0.00098 " " "

and, in two hours after firing, fishscaling began. Kerstan then took stock that showed much fishscaling and fired it with ground coat that contained ethyl alcohol instead of water in the slip and quince-seed extract instead of clay. No fishscales appeared in twenty days. Kerstan went on to show that the tiny "crystallites" or "shiners,"[127] which have often been considered a separate defect, are merely minute fishscales. His interpretation of the effect of underfiring on fishscaling, which has been so frequently noted,[128] may be criticized, however, for he suggests that the lack of diffusion of iron oxide into the enamel causes a concentration gradient that in turn causes mechanical stress from expansion differences. A better reason may be that good adherence is not fully developed during insufficient firing and less hydrogen pressure is therefore necessary to cause scaling. Hansen and Irwin[129] have suggested increasing adherence to minimize fishscaling.

It is difficult to picture the extremely localized fractures that are fishscales to be results of the general mechanical stress that would be provided by expansion differences between the coatings and the metal. The enamel coating on the graphite plate (Fig. 29, p. 206) cracked during cooling, but there was no evidence of anything that resembled a fishscale.

(2) Relation of Blistering and Boiling to Fishscaling

The following research has been designed to find out if hydrogen is the cause of fishscaling and to demonstrate the mechanism of fishscaling by experiment. First, the relation between blistering and boiling in the soft enamel and fishscaling in the hardened enamel will be shown. The relation should be obvious, for if hydrogen effuses at high temperatures to cause blistering it must certainly effuse at lower temperatures when the solubility of hydrogen in steel so sharply decreases. This does not imply, of course, that all steels that boil or reboil will fishscale, because complexities in the steel-hydrogen system and permeability and adherence of the enamel may act to suppress the formation under the enamel coating of the critical aerostatic pressure necessary to cause fishscaling.

To demonstrate the relation between blistering and fishscaling, a heavy section of plain carbon steel, 1 by 1½ by 5 inches, was prepared in the standard manner, dried 20 minutes at 115°C. (240°F.), and fired with an uneven application of blue ground coat. For so thick a section, 20 minutes at 115°C. (240°F.) is plainly insufficient for the removal of the hydrogen absorbed during the pickling. In fact, the increased rate of diffusion that occurs at 115°C. (240°F.) actually operates to drive hydrogen into the steel as well as out of it. During firing, as would then be expected, the coating blistered badly (see Fig. 33). It is interesting to note

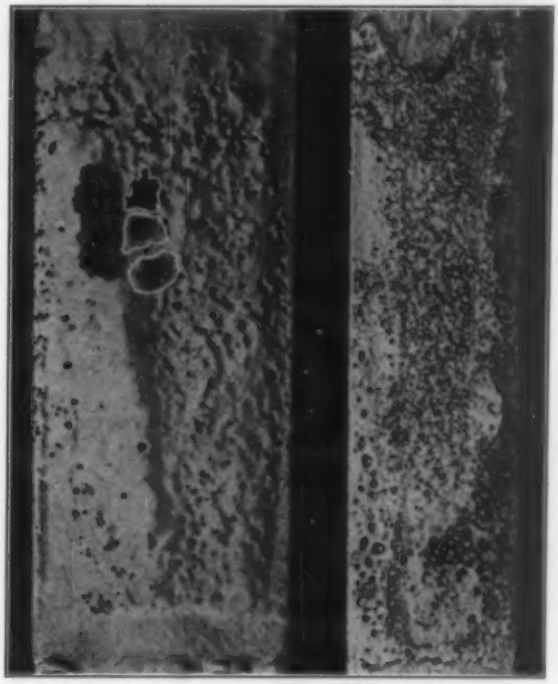

FIG. 33.—Heavy steel bar enameled according to standard procedure, baked 20 minutes at 115°C. (240°F.) and fired with an uneven application of blue ground coat, showing blistering and fishscaling caused by hydrogen absorbed during pickling; (*left*) front view; (*right*) side view.

that the side blistered much more severely than the face, for it has been pointed out that hydrogen dissolved in steel diffuses interstitially through the iron lattice and that impurities or discontinuities hinder this diffusion by trapping the gas as molecules or by retaining it by forces of a chemical nature. Therefore, the rolling, or banded, structure of steel sheet and plate should show directional properties in regard to hydrogen diffusion that should become stronger with increasing content of impurity or increased banding. This is why the specimen in Fig. 33 shows greater blistering on the side than on the face, for the piece contains about

[124] 198. [125] 212. [126] 199. [127] 175.
[128] 29, 30, 32, 105, 126, 175.
[129] 145.

0.18% of carbon and has been rolled parallel to the face. The phenomenon also explains why so much trouble is encountered in "black-edging," where heavy applications of enamel are applied on the sheared edges of heavily rolled sheet, and why it is difficult, even with thin sheets, to bake out dissolved hydrogen.

On the face of the specimen in Fig. 33 are shown three "fishscales," "chips," "pop-offs," or whatever one may wish to call them. These pieces left the coating shortly after cooling with an explosive violence that has been observed by many investigators and has been demonstrated artificially in the first part of the present paper (Fig. 9, p. 192). Such an explosive reaction suggests gas pressure rather than mechanical stress, especially when it is seen that the chips overlie large blisters that were caused by gas effusion themselves. It is also significant that the chipping has preferred the thick glazed seam of enamel, for much has been written showing that thicker coatings are more amenable to the defect. Increasing the thickness of the coating obviously decreases the chance for the hydrogen to escape and thereby to form the collection of gas under pressure.

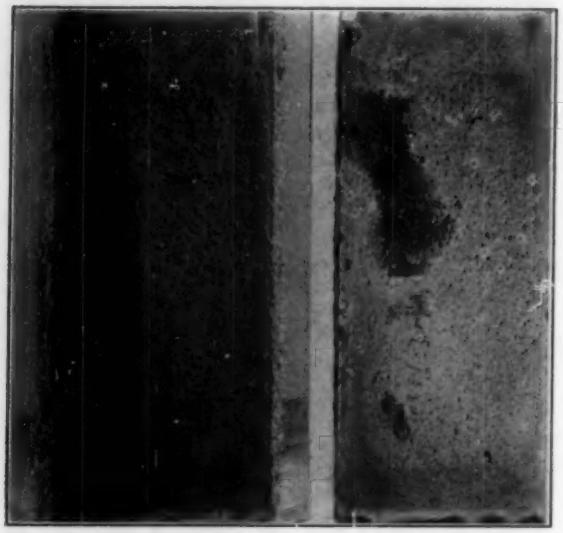

FIG. 34 (*left*).—Specimen shown in Fig. 33 placed in previously boiled water at 95°C. (200°F.) two days after firing. Note location of bubbles.

FIG. 35 (*right*).—Same specimen after immersion in water for 2 hours at 95°C. (200°F.)

To illustrate the reactions that have been postulated herein, the bar was placed in previously boiled water at 95°C. (200°F.) two days after firing. In about a minute, bubbles had formed as shown in Fig. 34, and they continued to form as long as the specimen was immersed.

There are several important features to note in Fig. 34. First, many of the gas bubbles appear exactly at centers where blisters had risen in the enamel during firing two days before. (Several large bubbles left the scaled area just before this photograph was taken.) Reboiling is characterized by a tendency of the blistering to recur at the same loci,[127] and the concurrence of bubbles and blisters here gives additional proof that most of the blistering during firing was not caused by carbon oxides, in spite of the fact that the steel contained much more carbon than does enameling stock. Secondly, there are no gas bubbles on the surface of the thick, glazed seam. As the effusion is otherwise quite general over the whole specimen, it is logical to assume that hydrogen is being liberated under this seam but that the thickness of the layer prevents its escape. In a short period of time, nearly the whole seam was blown away by the accumulating hydrogen, thereby justifying this assumption. Lastly, the bubbles are much more numerous on the sides than on the faces, concurring with the observations just noted on blistering and on hydrogen diffusion. Figure 35 shows the same specimen after two hours of immersion. Scaling has been greatly accelerated proportionately with the great acceleration in diffusion of hydrogen that occurs when the temperature is increased to 95°C. (200°F.). The glazed portion of the thick seam has been exploded away by hydrogen, revealing badly blistered enamel. Some unusual scaling, resembling "eyes," has also occurred at points of gas evolution where the earlier enamel blister had sealed over with a thin glazed layer.

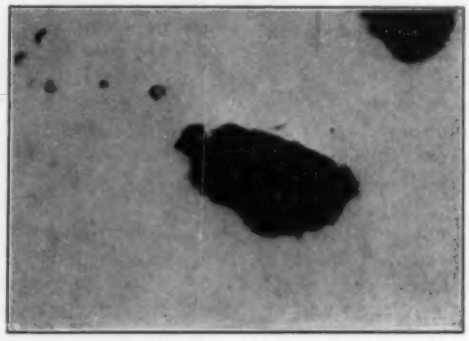

FIG. 36.—Fishscale in cover coat directly overlying blisters in ground coat.

Fishscaling in cover coats is less frequent than in ground coats, which difference may be explained as due to differences in refractoriness, in permeability to hydrogen of the two coats, and to the reduced quantity of hydrogen that is likely to be present in subsequent firings. It has been explained that hydrogen is quite rapidly lost during repeated firings and that, after the first firing, hydrogen will not be so quickly replenished by iron-moisture reactions because the first coating tends to protect the metal. Nevertheless, hydrogen can cause chipping and scaling in cover coats, too, as is shown in Fig. 36. Here the scale has overlain obvious blisters in the ground coat and therefore subscribes to the same reasoning used for the previous thick seam of ground coat. The confusing observations in the literature indicating that fishscales originate at various depths in the enamel[130] may be explained simply as due to the

[130] 64, 165.

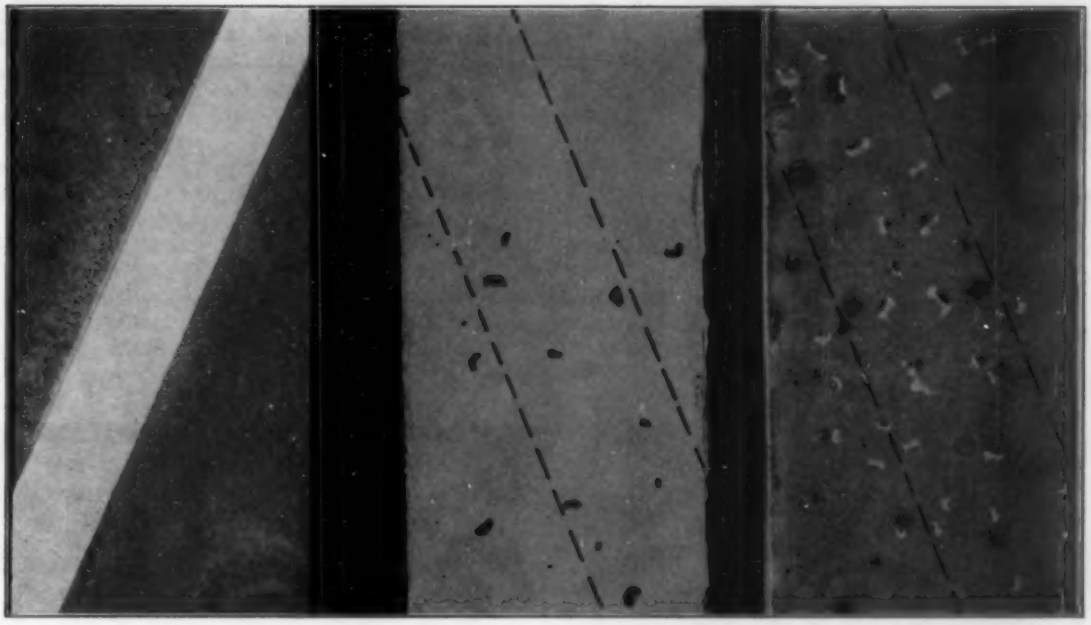

FIG. 37.—*Left*, carburized diagonal area on back of copper-plated steel plate; *middle*, baked unfired slip of second ground coat on front of plate; *right*, second ground coat after firing.

various layers in the enamel to which the gas must diffuse before being hindered sufficiently to develop pressure. In the particular case shown in Fig. 36, most of the ground coat remained on the steel.

Hydrogen retained in steel by carbon can also be released during temperature changes to produce fishscaling just as it does blistering. An interesting example is shown in Fig. 37. A customary steel plate, without holes, was electrolytically copper-plated and machined diagonally on one side as shown in Fig. 37 (*left*). The plate was then carburized at 950°C. (1750°F.) for 15 hours. The copper was removed with nitric acid, and a plate remained that was uniformly low in carbon content except for an indented diagonal area on one side where carburization had proceeded to a depth of about 0.03 inch. The plate was prepared with the standard enameling procedure, sprayed with blue ground coat, and baked at 115°C. (240°F.) for 30 minutes. This baking period sufficed to remove ordinary dissolved hydrogen because no blistering occurred on the front, low-carbon face during firing. Blistering did occur over the carburized area on the back face, but the following evidence, as well as that cited previously, indicates that even the blistering there was not due to carbon so much as to hydrogen that had become associated with the carbon during pickling. Two days after firing, fishscales began to appear on the front, low-carbon face, first, over areas corresponding quite well to the high-carbon diagonal on the opposite side of the plate, but later over the whole face (see Fig. 37 (*right*)). Thus, during firing, hydrogen had been liberated from the carbon immediately to cause blistering on the back face over the carburized area; it also diffused later into the steel from deeper-seated portions of the carbon-rich region to cause fishscaling. In the short firing period, the hydrogen could not diffuse through to the opposite face, but it did arrive there two days later to cause fishscaling.

Another layer of ground coat was then applied, and, during baking at 115°C. (240°F.), the hydrogen effusion on the low-carbon side of the plate became so severe that *scales of the baked slip were exploded off the specimen* (see Fig. 37 (*middle*)); it is again noteworthy that these "slip scales" in most cases have occurred exactly over the underlying fishscales. The steel is actually visible under several of the "double scales." The specimen was fired regardless of the damaged slip, and the second coat continued to fishscale as shown in Fig. 37 (*right*). Here again many fishscales have formed on the sites of former scales.

In the same manner, hydrogen may be liberated from occlusion in inclusions or cavities during firing and may reach the surface only after the enamel has cooled. Such a case is illustrated in Fig. 38. Two steel disks cut from a two-inch bar of plain carbon steel were welded together and rolled just as in the experiment shown in Fig. 10 (p. 193). In that experiment, hydrogen that was absorbed during pickling by the compound disk was trapped at the unwelded portions of the interface and developed sufficient pressure there to blister the steel. In the present experiment, less hydrogen, of course, was absorbed during the shorter pickling time and was therefore insufficient to cause blisters or defacement of the steel. Nevertheless, hydrogen collected there, and this dissolved during firing, though not rapidly enough to appear as blisters in the enamel. In fact, ten days after firing there was still no evidence of hydrogen defects, but soon thereafter a small fishscale appeared. The case is an excellent example of the "delayed" fishscaling that is so-

troublesome to enamelers and shows how deliberately the pressures may increase. At the end of six weeks about two dozen fishscales had appeared (Fig. 38 (*left*)). The piece was then inserted in an oven at 200°C. (390°F.) and in five minutes the number of fishscales increased to more than 100 (Fig. 38 (*middle*)). The temperature was increased to 250°C. (480°F.), but the scaling had stopped as suddenly as it had begun, indicating that all available hydrogen, probably just that quantity freed from occlusion during firing, had effused from the steel. To prove that mechanical stresses had nothing to do with the defect, the plate was heated rapidly to 250°C. (480°F.) and quenched in water. No additional scales appeared, nor did another scale appear in the succeeding two months.

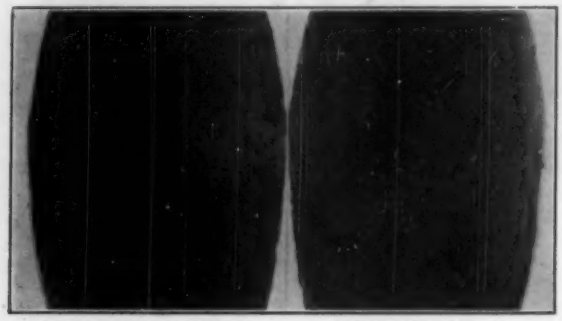

FIG. 38.—*Left*, fishscales on compounded disk 6 weeks after firing with blue ground coat; *right*, same disk after heating for 5 minutes at 200°C. (390°F.).

The progress of hydrogen as it diffuses through the steel can be followed by observing the train of defects that it leaves in its wake. The mechanism of "delayed fishscaling" is graphically portrayed by the following simple experiment (Fig. 39). A bar of plain steel, $^3/_4$ by $^1/_2$ by 5 inches, was drilled centrally and longitudinally with a $^1/_4$-inch hole, much as in the other experiments, and the hole was plugged and welded. A glass rod was placed in the hole before sealing to decrease the volume of the cavity. The specimen was prepared in the ordinary procedure, baked at 115°C. (240°F.) for over an hour to drive out all dissolved hydrogen, and fired with blue ground coat. During firing, the hydrogen, which had occluded in the cavity during pickling, re-dissolved and diffused through the two thinner walls, each of which was $^1/_8$ inch thick, and caused a long seam of blisters directly overlying the cavity on each of the two flat faces. No blisters appeared elsewhere. Before the piece had cooled, most of the blistered enamel on both faces exploded away in large chips. In the next few hours, the enamel immediately bordering on the blistered seams exploded away in large chips; one day later, enamel still farther away was chipping, and so on. As time passed, the fishscaling progressed to areas ever farther from the cavity, and the chipping occurred less at the metal surface and more in the coating itself, finally appearing as the customary fishscale. The fishscales also became smaller and occurred less frequently, finally appearing as tiny specks, which are apparently the "crystallites"[131] that are often described as a separate defect.

The important thing to note in Fig. 39 is that the hydrogen diffusion directly over, and very close to, the central cavity has been so severe that the metal is completely bare and that at greater distances the fishscales become progressively smaller and fewer. On the narrow faces, $^1/_4$ inch and more away from the hole, fishscales did not appear until several weeks after firing, and they were very small. The specimen had been placed in a container immediately after cooling, and at periodic intervals the chips and scales were collected. The chronology of blistering → fishscaling → delayed fishscaling is shown in Fig. 40. Each group of scales

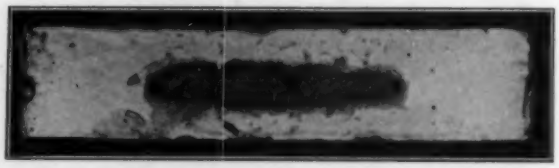

FIG. 39.—Blue ground coat on steel bar with central cavity, showing train of defects caused by hydrogen occluded during pickling and liberated during firing.

represents the enamel exploded from just one of the blistered faces between the intervals of gathering. Note the large bubbles in the early chips, and the gradual disappearance, first, of bubbles, and then black oxide as the diffusing gas slowly moves away from its origin; also note the corresponding decrease in the amount of chipping. At the end of one week, the chipping occurred almost solely within the enamel coating itself, for effusion had become so slow that the gas almost escaped through the enamel before sufficient pressures were obtained. When effusion is slow, the variations in permeability of the various zones in an enamel coating become important factors. Apparently the most impermeable section of a vitreous enamel coating is the outermost glazed layer.

(C) Other Defects

Other defects in enamel coatings in addition to those already discussed will be mentioned briefly to point out that the effusion of hydrogen from the steel during enameling may *indirectly* influence the formation of other defects.

(1) Copperheads

For example, "copperheads"[132] are plainly due to local concentrations of iron oxide, and yet Cook[133] finds that longer pickling periods are conducive to copperheading and that some irons are more susceptible than others. Several other observations at least imply that hydrogen in some cases is also present

[131] 199.

[132] 22, 36, 40, 48, 56, 62, 63, 77, 78, 85, 88, 89, 93, 94, 98, 103, 113, 123, 126, 130, [illegible]2, 135, 137, 144, 145, 148, 152, 156, 175, 188, 191, 196, 202, 210, 218.

[133] 135.

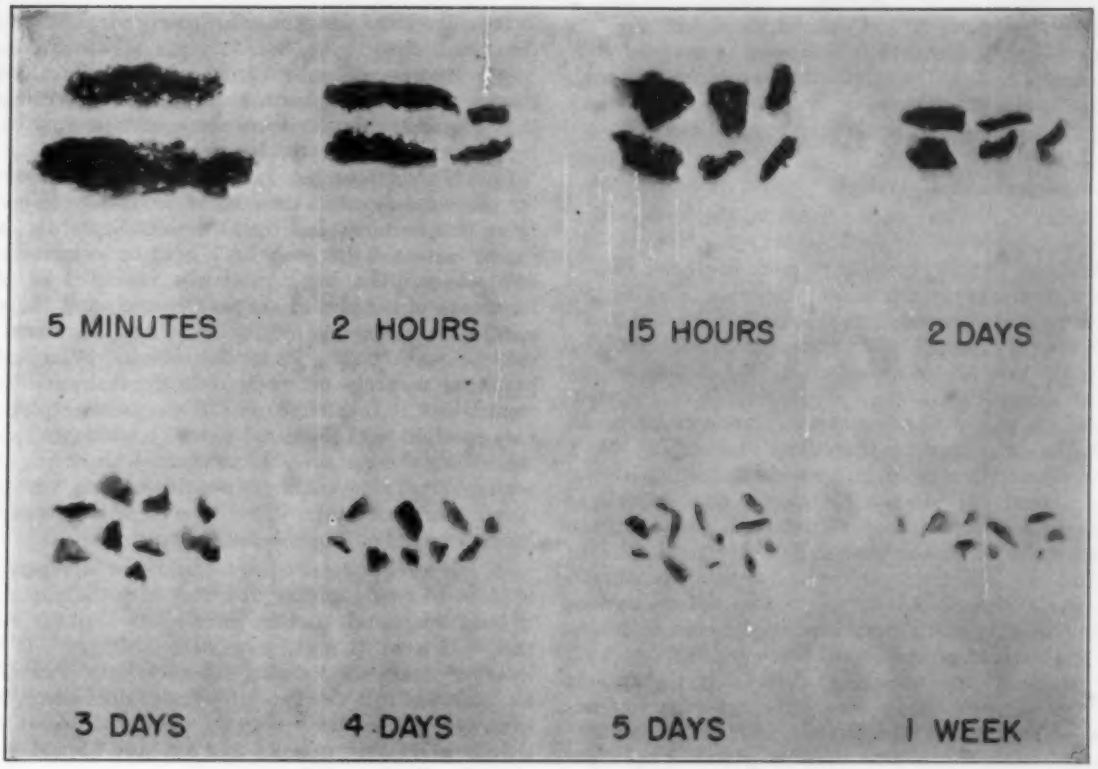

FIG. 40.—The chronology of blistering and fishscaling illustrated by groups of scales exploded by hydrogen from one face of specimen in Fig. 39 during time intervals as noted.

during the formation of copperheads[134]; Schaal and Fuller[135] believe that copperheads are related to reboiling, fishscaling, and to gas evolution in general. It might also be pointed out in addition that if the hydrogen evolution is sufficient to lift the enamel off the steel and expose the bare steel to an oxidizing atmosphere, copperheading will result. A particularly interesting case of copperheading may be observed in Fig. 37 (*right*), where a great range of copperhead-type blemishes has resulted directly from the evolution of hydrogen that occurred during the baking period of the enamel slip. It will be recalled that, in this experiment, carbon in the steel had retained so much hydrogen from the pickling operation that evolution of the gas caused fishscaling in the first layer of ground coat and that continued evolution from the loci of these fishscales caused "slipscales" to form in the slip during baking and while coming to temperature during firing. Where the fused enamel did not flow over these bare areas and completely absorb the oxide, copperheads and other blemishes resulted. Well-exposed spots were copper-colored, and less exposed spots were black, which conforms to the various oxides of iron that would result from variously oxidizing conditions.

Gas evolution during the "boil," of course, is similarly effective. The correlation between copperheads and hydrogen in the steel is therefore obvious; and an important point to note is that the increase in hydrogen effusion that occurs at baking or early firing temperatures may lift or explode away small pieces of the enamel slip, exposing the steel surface to oxidation.

(2) Black Specks

"Black specks"[136] in most cases are probably closely allied to copperheads and represent smaller areas of lesser oxidation, hence, Fe_3O_4. Here again the defect is related uncertainly to pickling,[137] but certainly to blistering and boiling,[138] to the iron,[139] to the furnace gases,[140] and to incorrect drying.[140] Black specks also appear on the specimen in Fig. 37 (*right*).

(3) Blister-Type Defects

"Pinholes,"[141] "pimples,"[142] and "glass eyes"[143] are apparently the result of gas evolution during firing.

(4) Fishscale-Type Defects

"Shivering,"[144] is another enamel defect. "Pop-

[134] 48, 148, 191, 196, 218.
[135] 62, 88, 89.
[136] 17, 23, 24, 62, 68, 72, 77, 78, 85, 88, 89, 103, 109, 111, 126, 142, 162, 175, 177, 180, 184, 187, 195, 208, 218.
[137] 103, 142, 162.
[138] 62, 78, 88, 89, 177.
[139] 24, 72, 162.
[140] 162.
[141] 35, 47, 58, 69, 77, 126, 158, 175, 188, 213.
[142] 36, 47, 77, 126, 175.
[143] 175.
[144] 9, 175.

offs,"[142] "jumpers,"[143] and some cases of "chipping"[145] can be identified as defects that may be caused by an effusion of hydrogen underneath the hardened enamel, as are fishscales. "Bursting"[146] of the enamel on cooking utensils may well be due to the same mechanism.

(5) Miscellaneous Defects

"Cracking"[147] has been related to the composition of the metal[148] and to welds and to slag inclusions.[149] "Hairlines"[150] and "crazing"[151] quite likely are results of the shrinkage and mechanical stresses. "Curling,"[152] "tearing,"[153] "crawling,"[153] "lifting,"[154] "orange peel" and "ripple" finish,[153] and "knobs"[155] are other defects.

Thus there are plenty of enameling defects arising from causes other than hydrogen. The complete avoidance of hydrogen, could it be accomplished, would not guarantee perfect enameling. In seeking for a better understanding of the causes of enameling defects, one should list all possible causes and instead of entirely omitting hydrogen from this list, as has so often been done, one should not only be careful to include it but to regard it as a most prominent suspect. Because of its omnipresence and the various phenomena by which it manifests its presence, hydrogen at least should be considered when seeking the cause of practically any enameling defect. If the authors have seemed to overemphasize the importance of hydrogen as a source of enameling defects, it probably seemed necessary in order to compensate for the slight attention it has hitherto received.

IV. Conclusions

From the foregoing work the following conclusions may be derived:

(1) Hydrogen is inherently present in every steel and iron but in widely different amounts. The steel-making process is responsible for this initial hydrogen content because the solubility of hydrogen in steel is several thousand times greater at steel-making temperatures than it is at ordinary temperatures. The extreme supersaturation that results during cooling forces the atomically dissolved hydrogen to precipitate in every available discontinuity, however small, where it immediately recombines to form highly insoluble molecular hydrogen; and the nascent condition of the atomically dissolved gas encourages reactions with impurities in the steel. The resulting total retention of hydrogen is so great that surprisingly large quantities are held in steel.

(2) To this inherent quantity of hydrogen is added more hydrogen by the pickling operation in the steel plant to remove scale and in the enameling procedure for preparing the specimen, by ordinary rusting reactions, by welding, and by reactions during firing with furnace gases and with the moisture chemically held in the enamel slip.

(3) Hydrogen dissolved atomically in the steel may cause enamel defects because diffusion is exceedingly slow at ordinary temperatures and equilibrium may not be reached unless the steel is carefully treated.

(4) Hydrogen occluded in cavities as molecules will be released only when the steel is brought to enamel-firing temperatures, and then the solubility of the gas has so increased that very little need be lost into the atmosphere. The initial release is indicated by the formation of bubbles in the soft enamel, and the resolution is evidenced by the fact that blisters soon collapse and "boiling" subsides. Upon cooling, the hydrogen may again largely seek the discontinuities from which it originated, and the remaining portion may precipitate at the metal-enamel interface to cause the scaling defects already enumerated, providing the permeability of the coating is unfitted to the quantities of gas that precipitate. This type of action accounts for the cyclical nature of boiling phenomena.

(5) Hydrogen retained in inclusions or segregations of impurities may or may not react with the impurity to form compounds that are more or less stable in contact with iron than is molecular hydrogen. If no reaction occurs, the occluded gas will behave as molecular hydrogen in a cavity. If reaction does occur, the hydrogen will be liberated to the steel at temperatures that depend on the product that has been formed.

(6) Hydrogen retained by molecularly dispersed impurities, such as carbon, will also be liberated at certain elevated temperatures. The case of carbon is particularly interesting and is most important. The chemical bond between carbon and hydrogen, particularly between unstable cementitic carbon and atomic hydrogen, is very strong, and large amounts of hydrogen conveniently collapse around carbide particles to form, perhaps, a quasi-methane structure. These iron-hydrocarbon structures decompose during firing to liberate hydrogen, and the resulting boiling action at the enameled surface has been wrongly identified as a carbon-oxygen reaction. Carbon oxides compose a fraction of the blistering gases, but hydrogen predominates. The decarburization that is sometimes noted in surface layers may be due to hydrogen activity as well as to a carbon-oxygen reaction; and the observed effect of pearlitic segregations on blistering is abetted by the possible presence of molecular hydrogen occluded in the interdendritic interstices that characterize segregations. The relation of microstructure of the steel to enameling defects is largely coincidental because the solubility of hydrogen varies markedly with the phase changes. In regard to cast iron, hydrogen is associated with white iron, and the decomposition of the white iron liberates hydrogen, which in turn may cause many of the defects in cast-iron enameling. Steel with considerable carbon content may be successfully enameled if its hydrogen content is carefully controlled. Pure graphite may be enameled without significant boiling action, although adherence is poor.

(7) Because the liberation of hydrogen from steel

[145] 4, 18, 23, 24, 77, 116, 126, 175, 188, 201.
[146] 108.
[147] 4, 72, 77, 120, 126, 127, 175.
[148] 72. [149] 120.
[150] 21, 47, 65, 80–82, 106, 129, 163, 168, 175, 182, 188, 192, 207.
[151] 18, 24, 36, 77, 126, 136, 175, 188.
[152] 188. [153] 129. [154] 24. [155] 83.

occurs at temperatures that depend quite closely on the condition of the occluded gas, it should also be possible for the enameling industry to use some steels that contain large amounts of inclusions; that is, as has been shown, if the included matter is predominantly of a certain type, the impurity may react with the occluded hydrogen to form a compound that is stable enough at enamel-firing temperatures to prevent liberation of critical quantities of the gas. Given a steel with a certain predominating type of impurity, the problem then is to select an enamel that matures at a temperature that is below the temperature at which the steel releases its hydrogen or at a temperature that is sufficiently above that of hydrogen liberation so that the gas may escape while the coating is porous.

(8) A primary cause of (*a*) "fishscaling," "delayed fishscaling," and "shiners," without important exception, (*b*) a cause of "pop-offs," "jumpers," and many cases of "chipping," and (*c*) perhaps of "bursting" is hydrogen which effuses from the iron or steel at temperatures where the enamel is rigid. "Delayed fishscaling" is the result of a sustained, slow effusion.

(9) A predominating gas reaction in producing the blistering and bubbling phenomena in molten enamel on steel and, very likely also on cast iron, is the evolution of hydrogen from the steel rather than the reaction of carbon and oxygen to which the phenomena are usually ascribed.

(10) "Copperheads" and "black specks" are indirectly related to the hydrogen content of the enameling stock by virtue of the relation that exists between these two types of defect and blistering and fishscaling.

(11) This paper is presented to show the effects of hydrogen in causing enamel defects. It is realized that good enamel stock must meet other requirements, such as workability, resistance to warping, etc. The investigation is to be continued, directing the study to the lower carbon compositions commonly used commercially. The present investigation indicates that when the steelmaker and the enameler approach the problems of providing steel and the enameling of it with due consideration of the relation that hydrogen bears to the enameling process the tasks of both should be lightened.

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Columbus, Ohio

DISCUSSION OF "STABILITY OF A KILN STACK" BY T. W. GARVE*

By F. H. Norton

Mr. Garve has attempted a rather difficult task, that is, the mathematical computation of the forces on a cylinder exposed to a moving fluid. Even with the great advances made in fluid dynamics in the last twenty years, it is still difficult to compute mathematically the force acting on the simpler types of body. This follows because the force is not due entirely to the pressure on the windward side, but it is also caused by the vacuum created on the leeward side due to the vortex formation, a condition not taken into account in the article referred to.

The resistance of a solid body in a moving fluid is made up of two parts, namely, the surface friction and the turbulent resistance. A thin plate edge to the motion would have a resistance almost wholly frictional, whereas if it were face to the direction of flow, the resistance would be mainly turbulent. The well-streamlined body of the airship is designed to minimize the turbulent resistance so that the total resistance is far less than for a sphere of the same diameter.

A cylinder exposed to air flow would have a force acting on it much smaller than would be computed by the dynamic pressure of the wind on the frontal projected area. The force factor in the case of a cylinder would be approximately 0.4, whereas for a rectangular plate with the same frontal area as the cylinder the factor would approach 1.0. There seem to be no very good data on a large scale for square prisms, but undoubtedly there is a great difference in the force acting on a square stack, depending on whether or not the face or the diagonal is normal to the wind.

Perhaps the best work on cylindrical stacks is given in a paper by H. L. Dryden and G. C. Hill, "Wind Pressure on Circular Cylinders and Chimneys," *Bureau of Standards Research Paper*, No. 221, 1930. Not only were the forces on cylinders in the wind tunnel studied, but actual readings were taken on full-sized stacks in the open wind. It is recommended in this paper that an assumed load of 20 lb. per sq. ft. on the projected area at a wind speed of 100 miles per hour may be considered to be a fairly conservative value. The writers also point out that local pressures may reach very high values, but this would not have to be taken into account in masonry construction.

Reply by Mr. Garve†

I appreciate Dr. Norton's reply and thank him for his contribution but should emphasize that I did not attempt a scientific investigation of the intricacy of air currents. I merely presented a mathematical proof of a condition fully recognized and agreed by engineers. Design engineers know of the existence of low pressure or vacuum on the leeside of a stack or other structure but are waiting for the scientist to tell them how to put that vacuum into calculation. I presented a basis for designing a safe and economical stack.

There are many problems we cannot solve absolutely, but by such calculations, soundly based, we can approximate the solution, and these approximations give the engineers a solid foundation for designing (in this instance) stacks which will safely withstand the wind pressure.

Note the following corrections:

(1) Right-hand column, p. 152, the first formula, $w \sin^2 \alpha \cdot \sin \alpha = w \sin^2$, should read as follows:

$$w \sin^2 \alpha \cdot \sin \alpha = w \sin^3 \alpha.$$

(2) Right-hand column, p. 153, the equation, $\frac{113{,}000}{7.5 + 7.5} = 2050$ lb., should read,

$$\frac{113{,}000}{7.5 \times 7.5} = 2010 \text{ lb.}$$

* Received May 8, 1940.
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JOURNAL REFERENCE: The journal name appears in italics, followed by the volume (bold-faced), issue number (in brackets), page numbers, and year (in parentheses).

July, 1940
19—7

Abrasives

Grinding, polishing, and buffing light [aluminum] alloys. ANON. *Light Metals*, **3** [25] 54–55; [26] 80–84 (1940); abstracted in *Bull. Brit. Non-Ferrous Metals Research Assn.*, No. 129, p. 76 (1940).—A survey based on recent literature, with a bibliography of 26 items, is given.

PATENTS

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Abrasive article. J. A. BOYER (Carborundum Co.). Can. 388,202 and 388,203, April 23, 1940 (June 27, 1938; in U. S. June 28, 1937). Can. 388,204, April 23, 1940 (July 2, 1938; in U. S. July 6, 1937). G.M.H.

Abrasive or polishing composition or article. W. W. TRIGGS (E. I. Du Pont de Nemours & Co.). Brit. 520,262, May 1, 1940 (Oct. 28, 1938).

Abrasive wheel and like tools. K. R. G. FISH. Brit. 520,060, April 24, 1940 (Oct. 26, 1938).

Apparatus for polishing sheets. D. D. JOHNSTON. U. S. 2,199,135, April 30, 1940 (Dec. 21, 1936).

Boron carbide composition and method of making. J. A. BOYER (Carborundum Co.). U. S. 2,200,258, May 14, 1940 (May 9, 1938).—A method of making a metal-bonded article containing boron carbide comprises alloying the boron carbide by a fusion process with sufficient metal to form, upon fusion and solidification, an alloy, the metal components of the alloy having lower melting points than boron carbide, in which the metal forms a substantially continuous matrix for the deposited crystals of boron carbide, disintegrating the alloy so formed, and thereafter bonding the disintegrated particles at a lower temperature than that used in forming the original alloy.

Buffing compound. E. E. SEELEY. U. S. 2,200,726, May 14, 1940 (May 20, 1939).—An abrasive compound comprising a resinous alcohol-soluble lac of the order of shellac, a relatively nonaqueous solvent therefor, a resin which is oil soluble, and a major percentage of abrasive material.

Buffing tool. E. W. HALL. U. S. 2,198,283, April 23, 1940 (Sept. 1, 1938).

Centering points for lathe, grinding machine, etc. A. TSCHERNE. Brit. 519,612, April 10, 1940 (June 22, 1939).

Centerless grinder. F. S. HAAS (Cincinnati Grinders, Inc.). U. S. 2,199,457, May 7, 1940 (Oct. 22, 1938).

Cleaver and knife sharpener. P. R. BOOTH AND F. R. BOOTH. U. S. 2,200,614, May 14, 1940 (April 4, 1938).

Coated abrasive. N. E. OGLESBY (Behr-Manning Corp.). U. S. 2,199,752, May 7, 1940 (Feb. 6, 1937).

Composite abrasive wheel. BAALIS SANFORD (Norton Co.). Can. 387,797, April 2, 1940 (Jan. 8, 1938; in U. S. Jan. 12, 1937). G.M.H.

Fluid-operated machine tools such as grinding machines. CINCINNATI GRINDERS, INC. Brit. 519,812, April 17, 1940 (Oct. 4, 1937).

Grinding machine. C. H. AMIDON (Norton Co.). Can. 387,799, April 2, 1940 (Feb. 1, 1938). G.M.H.

Grinding machine. F. A. JONES (R. G. Hodgson). U. S. 2,200,025, May 7, 1940 (Dec. 15, 1937).

Grinding machine for plastic flooring. G. P. GRANELL. U. S. 2,200,921, May 14, 1940 (April 24, 1939).

Grinding pistons. A. L. NELSON (Bohn Aluminum & Brass Corp.). U. S. 2,197,940, April 23, 1940 (May 28, 1936).

Grinding-wheel dresser. F. E. BROBERG (Dumore Co.). U. S. 2,199,149, April 30, 1940 (Aug. 13, 1938).

Honing device. K. W. CONNOR (Micromatic Hone Corp.). U. S. 2,200,573, May 14, 1940 (April 27, 1936).

Lapping machine. H. W. DUNBAR AND H. S. INDGE (Norton Co.). U. S. 2,198,377, April 23, 1940 (April 27, 1937). H. S. INDGE (Norton Co.). U. S. 2,200,173, May 7, 1940 (Oct. 30, 1937).

Making flexible abrasives. F. E. GALLAGHER (Behr-Manning Corp.). U. S. 2,198,766, April 30, 1940 (Dec. 22, 1932).

Manufacture of molded articles. NORTON GRINDING WHEEL CO., LTD. Brit. 519,539, April 10, 1940 (Sept. 23, 1937).

Means for dressing grinding wheels. E. L. MEESON. U. S. 2,199,053, April 30, 1940 (April 10, 1939)

Polishing apparatus. E. L. CODDINGTON (N. L. Barton). U. S. 2,200,592, May 14, 1940 (Dec. 10, 1937).

Polishing machine. A. L. BURROWS AND A. E. HENRICSON (Motor Products Corp.). U. S. 2,200,537, May 14, 1940 (Feb. 14, 1938).

Porous grinding disk. WILLIAM HADDOCK (Deutsche Norton-Ges. m.b.H.). Ger. 684,562, Nov. 9, 1939 (June 11, 1937); XII/67*c*. 1.—A porous grinding disk is made with its upper surface (outside the grinding zone) partly impervious to the grinding liquid or coolant. Those sections of the disk outside the grinding zone are rendered impervious to liquids; those sections not possessing this impervious property and absorbing the liquid have their absorbed liquid removed by centrifugal force or force of gravity. D.A.B.

Profile dresser for abrasive wheels. E. A. JOHNSON AND A. A. EMELIANOFF. U. S. 2,197,762, April 23, 1940 (June 30, 1938).

Purifying boron carbide. I. G. SHAFRAN. Russ. 52,084, Oct. 31, 1937; *Chem. Abs.*, **34**, 2542 (1940); addition to 50,979, April 30, 1937.—The boron carbide is heated at a temperature below redness with molten caustic until NH_3 is no longer evolved. The melt is then washed to remove the caustic, boiled in HCl, and dried.

Resin-bonded grinding wheel. J. R. ERICKSON (Norton Co.). Can. 387,800, April 2, 1940 (Dec. 10, 1938). G.M.H.

Tool-grinding fixture. J. J. HARTEN (Niles-Bement-Pond Co.). U. S. 2,200,883, May 14, 1940 (Sept. 1, 1938).

Art and Archeology

Church of the glass painters, St. Helens, York. JOHN A. KNOWLES. *Jour. Brit. Soc. Master Glass Painters*, **7** [4] 156–59 (1939).—Illustrated. M.B.H.

Contemporary work in stained glass by members of the Society. ANON. *Jour. Brit. Soc. Master Glass Painters*, **7** [4] 169 (1939).—Examples of recent window designs are illustrated. M.B.H.

George Eumorfopoulos. Anon. *Pottery & Glass Record*, **22** [1] 16 (1940).—George Eumorfopoulos, the famous connoisseur of Chinese art, died in London at the age of 76. He built up the world's finest collection of Chinese art, but five years ago he disposed of the bulk of it to the nation for $500,000, a sum far below that which could have been obtained in the open market. Mr. Eumorfopoulos was born in Liverpool and belonged to one of the Anglo-Greek families which established the great business of Ralli Brothers. He first collected English and Continental porcelain, but when he was about 40 years of age the fascination of Chinese art made an irresistible appeal to him. He spent a fortune on this hobby. A.B.S.

Fabulous pageant of Persian art. ANITA BRENNER. *N. Y. Times Mag.*, pp. 12–13, 22 (April 12, 1940).—The largest exhibition of Persian art ever held in the U. S. is on view at the Union Club, 1 East 51st St., New York, N. Y. It was assembled by the Iranian Institute under the direction of Arthur Upham Pope and includes 3000 precious objects of ceramic ware, bronze, silk, textiles, paintings, and books, almost all made for ancient kings. A short history and a description of Persian art are given. M.V.C.

Gild windows. JOHN A. KNOWLES. *Jour. Brit. Soc. Master Glass Painters*, **7** [4] 164–68 (1939).—Stained-glass windows of various churches in York are described and illustrated. M.B.H.

Inter-Society Color Council report. C. ROBERTSON. *Bull. Amer. Ceram. Soc.*, **19** [5] 200 (1940).

Making a pottery figure. ANON. *Pottery Gaz.*, **63** [728] 264–65 (1938).—The method of producing bone china figures is outlined and illustrated. L.S.

Pioneers of the trade. ANON. *Pottery & Glass Record*, **22** [1] 9–10 (1940).—In an old leather-backed volume written late in the 18th century are some interesting accounts of pioneers of the trade. More than a century ago "new facts" were found testifying to progress and advances in production made before machinery had been generally introduced to the industry, before railways had intersected the country, and when even canals with their barges laden with pottery were still a novelty. The Greeks and Etruscans were pioneers in art of every kind, and it seems almost a paradox to talk of progress in potting and the advance made in the 18th century by Wedgwood and others, when it is recalled that the great Josiah Wedgwood accomplished his greatest achievement in copying with exactitude the splendid Portland vase, which dates from early Etruscan days. English stoneware became famous for its utility and perhaps for the rich coloring and beautiful lasting glaze imparted to it by the pioneers of that branch of the industry, notably Miles Mason, whose ware is today treasured as evidence of another great advance. Potters contemporary with Wedgwood and those of later dates are too numerous to be named, although many of them are fully entitled to be called pioneers. Among those who came to England from the Continent and shared in developing the industry were a few whose products were distinctly different from the pottery then being made in England and whose work was so satisfactory and acceptable to English folk that they laid the foundation of distinct and varied branches of potting and introduced substances which extended the uses of clay products to many purposes which had been confined to materials such as wood, lead, pewter, and iron. As early as 1670 Dwight came to England and founded a works at Fulham. The Elers brothers initiated new processes which gave an impetus to the founding of the great pottery industries in North Staffordshire. Doultons, although of more recent date, are rightly regarded as pioneers in the branches of the pottery industry for which their works on the banks of the Thames at Lambeth have long been famous. The story of pioneer work in other parts of England reveals scattered and isolated efforts to supply Britain and the British Empire with acceptable pottery of all kinds. Many potteries failed to retain their grip on the trade; others were incorporated and their identity has disappeared. Those which are still successful include Worcester (founded by Dr. Wall), Derby Old Works, Bristol, Plymouth (where the name of Cookworthy is remembered), Bow, Chelsea, and the potteries at Poole in Dorset. A.B.S.

Potter's art at Cleveland. JAMES MARSHALL PLUMER. *Magazine of Art*, **33** [4] 212–17 (1940).—The 328 pieces in the current exhibition of Chinese ceramics at the Cleveland Museum of Art range from a neolithic painted pot from Kansu to a Ch'ing porcelain *sang de boeuf*. P. discusses the examples known as Tz'u-chou ware. The surface colors which typify this ware are cream and brown, alone or in combination, and there is often a transparent overglaze of deep blue or bluish green. The various techniques employed to gain the all-over patterns combine the surface and the clay form well. It is thought that the Korean potters learned the incising technique used on their famous celadon ware from the T'zu-chou. Illustrated. M.E.P.

Rebuilt vases 2000 years old. ANON. *Pottery & Glass Record*, **22** [1] 20 (1940).—Two Grecian chalices which for centuries lay broken and buried with the pieces scattered in two countries, have been reassembled, fragment by fragment, in England. The vases are now in almost as perfect a state as they were 2200 years ago. Pieces of the vases brought from Greece were bequeathed to the Dorset County Museum 40 years ago. Published descriptions of Greek pottery fragments in the Boston Museum, Boston, Mass., revealed that they matched those at Dorchester. The museums sent their fragments to the Ashmolean Museum, Oxford, where two complete vases were built up; one was kept in Oxford, and the other was sent to the Vatican. A.B.S.

Reclining Venus. *Coronet*, **8** [1] 107–108 (1940).—Two-page spread illustration in color of a ceramic statuette

by Gerhard Henning. It is of Royal Copenhagen porcelain. Henning has been associated with Denmark's great factory since 1909 and has specialized in capturing the precise tones of human flesh in small porcelains. M.E.P.

"Vitrail" (stained glass). E. VIOLLET-LE-DUC. Translated from French by Leicester B. Holland. *Jour. Brit. Soc. Master Glass Painters*, **7**, 139–45 (1937–1938); 169–81 (1938–1939).—A detailed account is given of design and execution in the art of glazing during the 12th and 13th centuries. Illustrated. See *Ceram. Abs.*, **17** [7] 249 (1938). M.B.H.

Work of the State Technical School, Zwiesel. B. MAUDER. *Glashütte*, **70** [5] 53–55 (1940).—Innovations in decorative technique worked out at the Zwiesel Technical School are illustrated. Horizontal, vertical, diagonal, or crisscross lines are cut in the glass over part or all of the surface of tumblers or bowls. Fine lines not only are necessary on thin-walled glass but form a better picture. Glass painting and engraving in conventionalized plant and figure forms are also shown. M.V.C.

PATENTS

Designs for:

Bottle. CARR-LOWREY GLASS CO. Can. 12,687, March 27, 1940. NORTHAM WARREN, LTD. Can. 12,705, April 9, 1940. G.M.H.

Bottle. N. F. STEUER (Owens-Illinois Pacific Coast Co.). U. S. 120,147, April 23, 1940 (Jan. 23, 1940).

Bowl. ONNIE MANKKI (Imperial Glass Corp.). U. S. 120,128, April 23, 1940 (Jan. 23, 1940). R. A. MAY (Duncan & Miller Glass Co.). U. S. 120,227, April 30, 1940 (Dec. 27, 1939).

Candlestick. ONNIE MANKKI (Imperial Glass Corp.). U. S. 120,408, May 7, 1940 (Feb. 19, 1940).

Chinaware, pottery, and porcelain. PARSONS-STEINER, LTD. Can. 12,704, April 9, 1940. G.M.H.

Combination glass dessert bowl and dish. A. H. NICHOLSON (Federal Glass Co.). U. S. 120,244, April 30, 1940 (Dec. 27, 1939).

Drinking glass. J. E. SPENCE (Hazel-Atlas Glass Co.). U. S. 120,146, April 23, 1940 (Jan. 24, 1940).

Jar. FRASIER SMITH (Hazel-Atlas Glass Co.). U. S. 120,473, May 7, 1940 (Feb. 23, 1940). E. W. FUERST (Libbey Glass Co.). U. S. 120,341, May 7, 1940 (Jan. 26, 1940).

Pitcher. EDWIN HAUB (Hazel-Atlas Glass Co.). U. S. 120,484, May 14, 1940 (Sept. 13, 1939).

Stemmed goblet. W. P. MORRISON (Bryce Bros. Co.). U. S. 120,136, April 23, 1940 (March 6, 1940).

Tumbler. W. J. LUNDY (Olean Glass Co.). U. S. 120,226, April 30, 1940 (Sept. 7, 1939). W. P. MORRISON (Bryce Bros. Co.). U. S. 120,134 and 120,135, April 23, 1940 (March 6, 1940).

Producing decorations on ceramic articles. RUDOLF LIEPACK (Keramisch-chemische Werke A.-G. vorm. Dr. Allers & Heller). Ger. 684,489, Nov. 9, 1939 (April 20, 1937); VI/80*b*. 23.02.—A method for producing decorations on ceramic articles having irregular curved surfaces comprises applying the design, etc., on a suitable transfer paper and transferring the design onto the ceramic article. For best results, the colors are ground with balsam, resins, and cellulose esters and are applied to the transfer paper by means of stencils; the design thus produced is transferred to the surface of the article to be decorated. D.A.B.

Producing signs or decoration on glass or other surfaces. R. J. COWAN. Brit. 520,217, May 1, 1940 (May 23, 1939).

Cements

British cement, lime, and gypsum industry in 1938. E. F. MACTAGGART AND W. E. EVANS. *Ind. Chemist*, **15** [168] 30–32 (1939).—Petrographic technique has been improved, particularly in regard to etching, so that the proportion of glass to crystalline constituents can be estimated. Progress in the study of the setting and hydration of cement has done much to reconcile the crystallization and gel theories. The greater fineness of modern cements demands the measurement of fineness based on sedimentation or elutriation principles. The lime industry has shown no outstanding technical developments in the past year. Gypsum is being increasingly used in the building industry, especially in plaster wall boards and partition blocks. H.E.S.

Determination of silica in Portland cement according to German specifications and in the presence of electrolytes. A. STEOPOE. *Tonind.-Ztg.*, **63** [25] 290–93 (1939).—German specifications prescribe the use of a large excess of diluted HCl for the decomposition of Portland cement and the separation of the silica. The addition of NaCl, NH_4Cl, and NH_4NO_3 has been recommended. By a series of tests, S. shows that the use of concentrated HCl in small excess gives good results and shortens and facilitates the operations. W.K.

Equilibrium in the system calcium oxide–phosphorus pentoxide–water. KELLY L. ELMORE AND THAD D. FARR. *Ind. Eng. Chem.*, **32** [4] 580–86 (1940).—Illustrated. F.G.H.

Flotation as applied to modern cement manufacture. G. K. ENGELHART. *Ind. Eng. Chem.*, **32** [5] 645–51 (1940).—Practical flotation separations of both an oxide mineral (calcite) and siliceous minerals (such as mica) are being made from highly complex argillaceous limestone pulps of extreme fineness. Most of the raw materials must be so finely ground, to free the mineral constituents, that the resulting pulps are slimes which were previously thought to be too fine for flotation concentration methods; one of the limestone pulps successfully processed had a fineness of 325-mesh with 60% of -10μ material. The success of the process in making these differential separations is attributed principally to the use of very small quantities of collecting reagents added in small increments to the pulp in each cell in a stage-oiling circuit. Modern type Portland cements of the highest quality are being produced by this process from materials previously considered both inferior and useless in cement manufacture. Illustrated. F.G.H.

Microscopic examination of Portland cement clinker. T. W. PARKER AND R. W. NURSE. *Jour. Soc. Chem. Ind.* [London], **58** [8] 255–61 (1939).—A method for polishing and etching specimens of Portland cement clinker for examination under the microscope is described. A reagent which etches $3CaO \cdot SiO_2$ selectively is ethylene glycol in absolute alcohol, the etching time being about 3 hr.; a similar reagent for $2CaO \cdot SiO_2$ is hydrogen fluoride vapor (10 to 20 sec.). The constitution of the matrix surrounding the silicate crystals cannot be determined exactly at present, partly because the glassy phase may or may not be etched with water, depending on its chemical composition, and cannot be identified separately from $3CaO \cdot Al_2O_3$ or $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$, respectively. The estimation of the contents of the identifiable compounds by the polished-section method agrees with values obtained by calculation if the clinkers are made from CaO, SiO_2, Al_2O_3, and Fe_2O_3, but when MgO and alkalis are also present there are some divergencies between the estimated and calculated values. G.R.S.

Physical structure of hydrated cements. S. GIERTZ-HEDSTRÖM. *Proc. Symposium Chem. Cements, Stockholm*, **1938**, pp. 505–33; abstracted in *Chem. Zentr.*, **1939**, II, 3467.—A comprehensive discussion is presented of the process of hydration and the development of the structure of concrete, volume ratios and velocity of reactions, and theories of the physical structure of cements and of the factors which affect this structure. M.V.C.

Pioneer but little known cement mill at Rockland, Maine. C. H. SONNTAG. *Concrete, Cement Mill Ed.*, **48**, 118–21 (1940).—This mill started operations in 1879 and shut down in 1882. Limestone "chips" too small for a lime kiln were run through a jaw crusher; clay was worked

up with water, and the raw mix was ground in an edge runner mill. The kilns were intermittent, and the product had to be hand sorted. It was packed in wooden barrels. The capacity was 200 barrels per week. Cement made at this mill could not compete with cheap European cement. W.D.F.

Properties of hydraulic blast-furnace slags. G. Mussgnug. *Arch. Eisenhüttenwesen*, **13** [5] 193–99 (1939).—The expected properties of the finished cement can be accurately estimated by grinding the slag to the usual fineness of cements, mixing it with proper additions (principally lime), dry-pressing the mixture into cylinders 5 cm. high and 5 cm. in diameter under a pressure of about 500 kgm./mm.², allowing them to set for 24 hr. in humid air and then for a few hours in flowing steam, and testing the sample following the usual practice. With the help of this test, M. examined the influence exerted by the variations of the blast-furnace processes on the properties of the finished cement. Temperature of slag formation has the greatest effect on the setting characteristics of the cements as well as the silica:alumina ratio of the slag, which is directly proportional to the strength and reduction of contraction of the cement. See *Ceram. Abs.*, **18** [1] 7 (1939). J.D.G.

Settling of dehydrated gypsum in the presence of various colloids. Rainero Stratta. *Ann. Chim. Applicata*, **29**, 115–22 (1939). K.R.

X rays and cement chemistry. W. Büssem. *Proc. Symposium Chem. Cements, Stockholm*, **1938**, pp. 141–68; abstracted in *Chem. Zentr.*, **1939, II**, 3467.—The crystal chemistry of various cement compounds and the theory of "active" and "inactive" Ca ions are discussed. The X-ray indices of the hydrates of compounds in the system $CaO–Al_2O_3–SiO_2–Fe_2O_3$ are described. M.V.C.

BOOK

Symposium on Lime. American Society for Testing Materials, Philadelphia, 1939. 124 pp. Price $1.50, cloth.—The following papers are included: (1) Variations in properties of dolomitic lime putties with the method of hydration, by John E. Conley; (2) Hydration of magnesium lime and the autoclave test, by F. C. Welch; (3) Manufacturing lime for the glass industry, by A. H. Nieman; (4) Factors affecting milks of lime employed in industry, by D. E. Washburn; (5) Quality of lime desired for water treatment, by Charles P. Hoover; (6) Prevention of after-precipitation in lime-treated industrial and municipal waters by threshold treatment, by Owen Rice; (7) Soil acidity and liming and factors that should determine standards for lime for soil, by E. O. Fippin; (8) Criteria for the evaluation of agricultural ground limestone, by R. M. Salter and C. J. Schollenberger; (9) Preliminary investigation of the determination of fluorine in lime, by C. J. Koehler; (10) Fundamental mechanics of calcination and hydration of lime and methods of control, by Victor J. Azbe; and (11) Lime characteristics and their effect on construction, by Walter C. Voss. R.A.H.

PATENTS

Manufacture of cement. Ritter Products Corp. Brit. 519,770, April 17, 1940 (July 3, 1937). A. H. Steven, (G. L. Cabot, Inc.). Brit. 520,149, May 1, 1940 (Oct. 12s 1938).

Enamel

American efforts in enameling. A. L. *Verre & Silicates Ind.*, **11** [1] 2–5 (1940).—The enamel industry in the U. S. has achieved such perfection of installation and has shown such great enterprise and ingenuity in finding new applications and uses for enamels and enameled objects that it is well in advance of the European industry. M.V.C.

Architect looks at porcelain enamel. W. S. Arrasmith. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 89–97.—Architects are attracted by the fact that porcelain enamel is impervious to soot, dust, and acids, is lightweight, and is particularly adaptable for remodeling work. The porcelain enameling industry has done a poor job of selling its ware, and only one architect in four or five knows porcelain. A. points out some of the objections to architectural porcelain, such as waviness, crawling, and inflexibility, and offers suggestions to remedy common complaints. Another disadvantage is the fact that few companies manufacturing architectural porcelain do their own erecting. Methods of application and installation should be standarized for the protection of all. F.J.Z.

Ball-mill practice. Harry Sechrist. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 136–47.—As ball size decreases, total milling time decreases. In a 3- x 4-ft. belt-driven mill using one half 2-in. and one half $1^1/_2$-in. balls, there is a 25% saving in production time over any other combination, and no unground frit is left in the mill. The loss in weight of the balls is practically the same in every combination of ball sizes used. If the balls are all of the same size, the mill lining may become grooved and wear out rapidly. Ball charge should always be kept at 50 to 55% of the mill volume for most efficient grinding. New balls should be added when the old ones have become worn down to $^3/_4$-in. size. The water content must be controlled accurately, as too much and too little water both increase milling time. Frit charges must be carefully checked; too large a charge requires much longer grinding, and too small a charge causes excessive wear on linings and balls. Milling at too high a speed can cause loss of set through heating up of the enamel. Tables and charts are presented. F.J.Z.

Cast iron for enameling purposes. Thomas G. Johnston. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 39–48.—J. presents a short résumé of early history in the enameling industry which might explain reasons for wide differences of opinion which still exist in regard to metal to be enameled. Present trends in cupola mixtures and operation are described. F.J.Z.

Causes of powder blisters in dry-process enamels. Perry McCollom. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 23–33.—A powder blister is defined as a covered cavity, spherical in shape and entirely free from foreign matter. A commercial leadless frit was purposely contaminated with various troublesome materials in amounts ranging from 0.001 to 0.10%; the milled powder was then applied on small iron plates, and the effects were noted. Most severe in producing powder blisters are such gas-evolving materials as sodium nitrate, soda ash, and barium carbonate. Undersmelted enamel caused some blisters, while cupola ash was found to be a major source of powder blisters. Several photomicrographs illustrate the various types and sizes of powder blisters. F.J.Z.

Cause of sunflowers in dry-process enamels. R. R. Danielson. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 34–38.—Sunflower is defined as the defect which occurs as a small elevated spot on the enamel surface, usually with a yellow center and often with what appears to be a greasy ring surrounding the spot. D. found that a very small amount of massive iron introduced into a batch of antimony- and lead-bearing enamel before or during smelting would promote sunflowers. Theoretically, the iron precipitates a lead-antimony mixture or alloy consisting of 52.37% metallic lead and 47.70% metallic antimony which forms the defect. F.J.Z.

Ceramic manufacturing developments of the Western Electric Co. A. G. Johnson and L. I. Shaw. *Bell System Tech. Jour.*, **18** [2] 255–79 (1939).—A general picture is given of the development work involved in the introduction of manufacturing processes for vitreous-enameled resistances, vitreous-enameled iron and copper base number plates, pressed-glass lenses, extruded and pressed porcelain

parts, and close tolerance ceramic insulators for use in telephone apparatus. The reason for undertaking the manufacture of these products, some of the major problems encountered in developing suitable processes, and the work done in overcoming these difficulties are described; several major contributions to commercial methods of manufacturing similar parts are included. H.E.S.

Ceramic materials for radiators. ANON. *Gesundh.-Ing.*, **62** [7] 86 (1939).—The German ceramic industry manufactures vitreous porcelain radiators in fine space-saving types. Satisfactory results are obtained. See "Radiators . . . ," *Ceram. Abs.*, **18** [10] 273 (1939). W.D.K.

Chicago Vitreous demonstrates improved architectural porcelain enamel for interiors. ANON. *Bull. Amer. Ceram. Soc.*, **19** [5] 203–204 (1940).

Closer control has resulted in improved finishes. G. I. BRUTON. *Enamelist*, **17** [4] 28–30 (1940).—B. discusses the advantages gained by closer control in preparing and applying enamel. L.E.T.

Developments in enamel technique in 1939. V. *Emailwaren-Ind.*, **17** [3–4] 7–8 (1940).—Developments in enamel technique in 1939 include: (1) new testing methods for determining hardness ("Testing . . . ," *Ceram. Abs.*, **18** [11] 292 (1939)); (2) attempts to establish factors for calculating the resistance to compression on the basis of tests; (3) values for the tensile strength of ground enamels and the effect of different constituents on hardness (*Jour. Amer. Ceram. Soc.*, **22** [1] 11–15 (1939)); (4) opacity and the effect of fineness; (5) values for thickness of coatings and grain size for certain opacifiers; (6) borax substitutes (in Germany), either the use of other materials or eutectic mixtures having a fluxing action or the introduction of refractory constituents in a more easily fusible form to economize on flux; (7) the preparation of batches without borax; (8) strontium carbonate as a new raw material; (9) in America, tests on sagging and changing of form with temperature of the metal to be coated (*ibid.*, [6] 176–79); (10) effect of raw materials, fineness of grinding, and other factors of preparation on the color of coloring oxides; (11) action of fluorine materials as preopacifiers; (12) question of adherence of enamels to iron and the existence of a film of iron oxide; (13) action of cobalt and nickel oxides; (14) furnace gases, steam, and carbonic acid as the cause of blister formations; (15) preopacification of enamels, new uses for enamel, and enameled objects; and (16) the use of waste pickling liquor in the manufacture of blocks. M.V.C.

Development of specifications that will meet building-code requirements. J. H. WILSON. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 98–104.—Rigid specifications will prevent unsatisfactory installations which make poor advertising for the use of porcelain enamel in architectural work. A building code must cover the attachment of the porcelain veneer and the protection of this veneer from deterioration over a period of time. The code should cover caulking, flashing, thickness of metal, and possibly the thickness of the enamel coat. A clause limiting the application of exterior loads on enamel panels to points well within their capacity for handling loads should be included. A discussion is included. F.J.Z.

Dipping methods. PAUL A. MALLONN. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 125–28.—Hand dipping and tong dipping are discussed. For ground coat, M. uses a fineness of 12% residue on a 200-mesh screen, accurately controlled; the enamel is aged 24 hr. and set up for dipping just before use. Sodium nitrite solution prevents rusting, but borax is usually used for setting up ground coats. Epsom salts are used to "make the enamel short." Constant use of the ground coat results in better dipping efficiency. Cover coats are ground to a fineness of 2 to 8% residue on a 200-mesh screen for dipping, Epsom salts being used for setting up. Clay is an important mill addition in dipping enamels. Improperly smelted enamels can cause considerable trouble. Domestic and imported clays are used successfully. F.J.Z.

Drawing compounds. G. W. DYKSTRA. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 63–72.—From a press-room standpoint, factors to be considered in drawing compounds include (1) ability to draw, (2) die life, (3) protection of metal surfaces, (4) ease of mixing and handling, (5) stability, (6) versatility, (7) cost vs. results, and (8) sanitation. D. describes chemical and physical tests which greatly simplify the complexity of the drawing-compound problem. A discussion is included. F.J.Z.

Early experiences in enameling cast iron. E. L. DAWES. *Bull. Amer. Ceram. Soc.*, **19** [5] 177–78 (1940).

Effect of variation of annealing between draws on the stamping of hollow ware. J. N. CROMBIE. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 113–25.—Three general steps in the annealing of metals are discussed, viz., stress relief, recrystallization, and grain growth. Mild steel, strained to values of deformation within certain limits and then annealed in a definite range of temperature, develops a condition of exaggerated grain growth, and this region of deformation, defined as "critical strain," is of great importance in the intermediate annealing of hollow ware. Microsections of strained specimens annealed for 2 min. at various temperatures up to 1600° F. are shown. F.J.Z.

Enamels free from borax. VIELHABER. *Emailwaren-Ind.*, **16** [47–48] 267 (1939).—When enamels containing lead were converted into lead-free enamels, many difficulties were encountered. Similarly, the manufacture of enamels free from borax is beset with problems which experience only can solve. Borax dissolves metal oxides easily, and it also dissolves white coloring oxides; an enamel free from borax, therefore, would not require as much opacifying material as one containing borax. All enamels without boric acid have a high expansion, although this is not always important. The defect of fly-specks can be prevented by purely technical precautions. M.V.C.

Enamelware. MOORE ENAMELING AND MFG. CO. *Steel*, **104** [14] 48–50 (1939).—A new continuous U-type furnace and the relocation of departments and equipment greatly increase the efficiency of an enameling plant handling a large volume of kitchen utensils. Production is raised to a capacity of 100,000 pieces of quality wear daily. H.E.S.

Formation of fish scales in sheet iron ground enamels. HANS BOCKSHAMMER. *Sprechsaal*, **72** [52] 595–98 (1939).—Fish scales are known to be caused by hydrogen which is produced by the reaction between the hydrate water of the enamel and the iron after prolonged or repeated firing. Most of the hydrogen escapes through the fused enamel layer during firing. Additions to the mill, such as quartz and alumina, help in removing it because the melt is held "open" longer. A certain part of the hydrogen, however, is absorbed by the sheet iron when hot and then released during cooling. Since the enamel layer is hard at 550°, the escape of the hydrogen is no longer possible below this temperature; a diffusion pressure is created against the enamel layer because the gas cannot escape. Since the cold material possesses less power to absorb hydrogen than the hot material, the gas pressure in the first case is lower, or no gas at all is present. Only insensitive enamels, because of their good adherence to the iron, can resist this diffusion pressure; in the case of less adherent enamels, fish scales are formed by the escaping hydrogen. Photographs are given. M.V.C.

Health hazards and their control in pickling operations. M. A. SNELL. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 72–84.—Vapors from all of the acid solutions used in pickling processes are irritating to the eyes, upper respiratory tract, and sometimes the skin. Toxic gases and vapors are sometimes evolved. Inhibitors for preventing the formation of toxic gases, good mechanical exhaust ventilation practice, and respiratory protective devices are described, and their use is advocated for the protection of pickle-room operators. F.J.Z.

Hydrogen diffusion in steel. T. G. BAMFORD. *Proc. Staffordshire Iron & Steel Inst.*, **53**, pp. 1–6 (1938).—Hy-

drogen diffuses in metals in the atomic state but not the molecular state. In the case of hydrogen in iron, diffusion is a lattice process, and grain boundaries play little part. When it reaches a contraction cavity, blowhole, or nonmetallic inclusion, it is converted to molecular hydrogen, in which form it cannot diffuse further and will develop very high pressure within the metal. Absorption of hydrogen during pickling decreases the deforming qualities (ductility) of steel. Hydrogen can be partly eliminated by suitable heating to red heat. A.B.

Ingot mold insulation. F. M. RITTS. *Steel*, **104** [22] 46, 61 (1939).—A new insulation of ceramic-coated cork reduces piping in killed steel ingots, permits repouring, eliminates carbon pickup and the entrapping of metallic materials, gives higher yield per ton and per ingot, and affords better regulation of ingot size. H.E.S.

Inspection, packing, and field problems. R. F. BISBEE. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 162–78.—Inspection is defined as control of quality working as the customer's representative and the management's guardian. Improved quality at a competitive cost is the best factor in increasing sales and profits. B. presents a detailed account of the methods used in a production plant to control incoming materials (including iron) and enamels, standards, and working conditions. F.J.Z.

Mat enamels. ANON. *Glashütte*, **69** [35] 634–35 (1939).—Dullness is usually considered a defect in enamels although it is sometimes required, as in the case of special decoration, blackboards for schools, etc. Mat enamels may be obtained most easily by the use of enamels which fuse difficultly or insufficiently, but a homogeneous effect cannot be obtained. Uniform, constant dullness may be obtained by using fusible enamels and adding refractory substances (feldspar, quartz, calcined kaolin, grog powder, or, preferably, finely ground porcelain) to the mill. A formula for mat enamels is given: borax 28, quartz 22, feldspar 25, cryolite 12, fluorspar 3, soda 8, and saltpeter 2 with additions to the mill of 30 parts by weight of enamel granules, 25 feldspar, 25 ground porcelain, 10 white opacifier, and 10 clay. Coloring oxides can be added. Ordinary enamels can be sanded to give a mat effect, but the process is complicated and may injure the surface of the enamel. A mat finish can also be obtained by immersing enamels in an acid bath of proper concentration. The acid can also be mixed with pipe clay, quartz, etc., and blown or painted on the fired enamel; the action of the acid is slower and easier to regulate. See *Ceram. Abs.*, **19** [2] 41 (1940). M.V.C.

Measuring the chipping resistance of enamels. PAUL L. SMITH. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 155–62.—S. classifies chips as (1) those that start at the outer surface of the enamel, and (2) those that start within the enamel. Photographs and graphic descriptions of each type are presented. Weight of application, differential expansion, humidity, radius of curvature, ground-coat structure, and adherence play parts in the first type of chipping, and a test of resistance to this type has been devised to give satisfactory results in a single laboratory. The characteristic features of the second type of chipping are the oval shape and smooth surface of the exposed ground coat. The elasticity of the cover coat, thickness of application, and thermal expansion are important in this type of chipping. S. briefly describes two tests for resistance to the second type of chipping. F.J.Z.

Powder ground for castings. VIELHABER. *Emailwaren-Ind.*, **17** [3–4] 8–9 (1940).—The thin ground enamel applied to metal castings before powdered enamels is not as important as that used in wet enameling; it preserves the metal from oxidation. Such ground enamels do not require borax, which is replaced by soda. A good batch which, with modifications, gives a satisfactory ground enamel contains 77 powdered water glass, 26 feldspar, 16 fluorspar, 2 pyrolusite, 1 cobalt oxide, 7 clay, and 60 water. M.V.C.

Powdered glass. V. *Emailwaren-Ind.*, **17** [1–2] 1–2 (1940).—Powdered glass varies in composition and is made from all kinds of glass; the only safe way to use it as an easily fusible source of silicic acid in the enamel batch, therefore, is to first make an analysis of an average sample. Some factories manufacture powdered glass especially, and the composition of this commercial variety is uniform. A constant composition can also be assured if the glass is fused at the enamel plant, but ordinary glass is too hard to fuse. A simple glass of the composition 2.45 mol. SiO_2, 0.47 mol. Na_2O, and 0.53 mol. CaO (molecular formula 71.80 SiO_2, 14.00 Na_2O, 14.20 CaO) fuses at about 845°. The lime content of this glass is too high for some enamels, but if it is replaced by other oxides (BaO, ZnO, PbO, K_2O, Li_2O), the softening point is raised. The fusing point of the enamel is important, and the heat expansion of the glass also affects the enamel. Lithium oxide glass is especially desirable although lime glass remains the best choice because it has a lower heat expansion and a lower fusing point. Glass containing zinc oxide is best for cooking utensils. M.V.C.

Proper handling of fuel oil. RICHARD J. BOYINK. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 129–36.—Two classes of fuel oils are discussed. "Gas oil" is any light fraction recovered from the distillation of crude oil after gasoline and kerosene have been removed. "Heavy fuel oil" is the heavy residual material remaining in the crude after the removal of all distillable fractions. Gas oil is a high-cost fuel, but it presents few fuel problems, while heavy fuel oil is low in initial cost but beset with combustion problems, particularly if not handled properly. Viscosity, pour point, flash point, and A.P.I. gravity are important considerations in evaluating fuel oils. The salt content and "BS&W" (bottom, sediment, and water) are also discussed. Oil is a flexible and readily available fuel which must be handled properly with proper equipment for maximum efficiency and lowest operating cost. F.J.Z.

Protecting metals by vitreous enamels. A. E. R. WESTMAN. *Can. Metals Met. Inds.*, **3**, 38–41 (1940).—A general review of the composition and properties of vitreous enamels and of the developments in the field during the last ten years is presented. E.P.

Recommended revision of sanitary cast-iron enameled ware tests. ANON. *Bull. Amer. Ceram. Soc.*, **19** [5] 199–200 (1940).

Removing rust and forge scale from iron, steel, and sheet-metal ware. RUDOLF PLÜCKER. *Beizerei* (in *Emailwaren-Ind.*, **14** [12]), **2** [3] 9–11 (1937).—A cheap solution for removing rust is made of a mixture of 750 gm. caustic soda, 875 gm. soda crystals, and 10 gm. potassium manganate or potassium permanganate in 12 liters of water. The dry mixture keeps well. After a few minutes in the solution, rust dissolves and can be wiped off. The metal underneath is in no way corroded and possesses a thin coating which protects it from rust for a short time. For cleaning off dirt, oil, colors, etc., a little glycerine is added without affecting the derusting action. For cleaning alone a mixture of 4 kgm. soda crystals, 250 gm. caustic soda, 125 gm. glycerine, and 16 gm. manganic acid potassium dissolved in 120 liters of hot water is recommended. Another chemical solvent is made of a paste of a drying oil (linseed or soy bean oil), soap, and a basic material like iron oxide. It is prepared by dissolving ordinary soap in water and mixing with oil in the proportion of 1:4; this emulsion is set aside for a few months to improve its strength. When applied to metal, it forms an adhesive film which can be pulled off when dry, taking the rust with it. One disadvantage of this process is that drying may take as long as 24 hr. Other good rust removers are the sulfonation products of anthracene residues or raw anthracene obtained in tar distillation (Karl Immerheiser). To an aqueous solution of 10 sulfonation products, 3 hydrochloric acid, and 1% oxalic acid, 10% tar oil and 1% castor oil are added, and the mixture is stirred to form an emulsion. The acids in the ordinary pickling bath cause some corrosion of the material, and to retard this reaction, especially in the case of precision instruments, certain additions such as organic "suloxide" can be made. Their use is treated briefly. M.V.C.

Sheet metal ground enamels. VIELHABER. *Emailwaren-Ind.*, **16** [45–46] 259–60 (1939).—Satisfactory cover enamels which possess good color, luster, etc., can be made without borax or boric acid, but if borax is not present in the ground coat, the well-known defect of speck formation appears. The problem of finding a solvent for impurities in the sheet metal which will not devitrify or a pickling process which will remove impurities can be solved by the American nickel dip or by the use of two ground enamels, since only the layer next to the metal need contain borax. Sodium phosphate has been considered as a borax substitute, but it, like borax, must be imported in Germany. M.V.C.

Symposium on dry-process problems. H. F. STALEY ET AL. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 48–55.—The need for the standardization of methods for testing the fineness of powders and methods of milling, smelting, and applying powders were discussed. The problem of acid resistance in dry-process enamels will bear considerable study. Ground coats were discussed. F.J.Z.

Symposium on fine ground enamels. E. C. AYDELOTT ET AL. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 3–23.—E. C. AYDELOTT: Grinding to 1 gm. on 200-mesh increased milling time approximately 25% and increased reflectance from $1^1/_2$ to 2%. Grinding to 1 gm. on 325-mesh created too many working difficulties to be practical. E. W. DIETTERLE: Enamel ground to 1 gm. on 325 mesh had too much set for the automatic spraying machines and required too long a time for grinding, but it reduced the weight of application by 40%, reduced chipping, and promoted better appearance. Present practice is to grind to 1 gm. on 200-mesh. C. T. GORDON: At a fineness of 1 gm. on 325-mesh, every enamel defect was greatly exaggerated. It is important to watch the ground coat carefully, and present practice is to grind to 2 gm. on 200-mesh. T. D. HARTSHORN: Grinding to 1 gm. on 200-mesh was quite satisfactory, giving improved appearance and higher reflectance and reducing chipping and material costs. H. believes that control of soluble salts in mill liquor has much to do with the success or failure of fine-milled enamels. J. B. SIMON: Enamels ground to 1 gm. on 325-mesh could not be used successfully. It was decided to drop the fineness of enamels in stages of 1 gm. until a fineness of 1 gm. on 200-mesh was reached. Opacity and milling time increased. NORMAN STOLTE: A better ground coat would be required for the use of fine-milled cover coats. Zinc-coated containers and sodium nitrite in fine-milled enamels caused trouble. Fine-milled enamels failed to stand up during the repeated firings required in decorating panels. Medium-grind enamels (1 gm. on 200-mesh) have worked well. S. discusses the effects of fine grinding on colors and presents several spectrophotometric charts. G. E. TERRY: Grinding to 1 gm. on 200-mesh has been standardized. Fineness of the ground coat was reduced to eliminate orange peel in the cover coat. Finer grinding reduced sagging tendencies and improved brushing conditions. Chipping difficulties have been practically eliminated, and T. intends to continue to grind finer in stages. J. J. BOEHLER: With enamel ground to 1 gm on 325 mesh, ground-coat defects were magnified. B. now uses 1 gm. on 200-mesh with success. F. L. MICHAEL: More rigid control is necessary in using fine-milled enamels. J. E. TREES: Finer milled enamels require proper setup for spraying, and finer screens should be used to take out coarse particles which cause trouble. F.J.Z.

Use of hydrated sodium antimonate as a mill addition for sheet enamel. LUDWIG STUCKERT. *Emailwaren-Ind.*, **17** [7–8] 23–25 (1940).—S. studied the behavior of hydrated antimonate as an opacifier in the form of a mill addition. The beneficial and injurious ingredients of the frit were determined. On the basis of these determinations, the beneficial ingredients (alumina, cryolite, fluorspar) were systematically varied and tested in order to find the optimal enamel for the hydrated antimonate. The effect of the opacifier on the transverse strength and the solubility of the enamel frit was tested; the antimonate had a good influence on both properties. The quantity of trivalent and pentavalent antimony dissolved out by 3% tartaric acid is small in all cases and lies below the standard amount of 6 mgm. per liter. Especially low and harmless is the quantity of trivalent antimony. Less than the standard amount of trivalent and pentavalent antimony is extracted with alkali-dissolving liquids. M.V.C.

Use of a settling test for determining fineness of porcelain enamels. M. H. WHITEHEAD. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 105–13.—The relationship existing between the settling test and the standard screen test is shown by data obtained on three types of enamels. The effects of specific gravity, temperature, and variable mill additions are discussed. The chief advantages in using the settling test are the savings in time and cost. F.J.Z.

Use of softened water in cleaning and pickling room practice. E. H. SHANDS. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 56–62.—Waters are classed as (1) very soft, containing up to 3 grains calcium carbonate per gal. or 50 p.p.m., (2) medium hard, containing 3 to 6 grains per gal. or 50 to 100 p.p.m., (3) hard, containing 6 to 18 grains per gal. or 100 to 300 p.p.m., and (4) very hard, containing over 18 grains per gal. or over 300 p.p.m. Substances which impart a definite hardness to the water are unfavorable for efficient pickling practice because of the precipitation of soapy emulsifiers by the calcium and magnesium carbonates. By using water that had been passed through a commercial zeolite softener, S. found that cleaner consumption was materially reduced, the sludge in the pickle tank dropped, and the efficiency of rinsing increased. A discussion is included. F.J.Z.

Vitreous-enamel pipes in building constructions. PAUL SOLL. *Gesundh.-Ing.*, **61** [36] 499 (1938).—The possibility of using vitreous-enamel pipes in building constructions is viewed skeptically by building contractors and engineers. Results obtained with these pipes are discussed. Possibilities and conditions for use are stated. W.D.K.

Vitreous-enamel pipes in sewer systems. M. MENGERINGHAUSEN. *Gesundh.-Ing.*, **61** [43] 622 (1938).—Results of tests made with pipes manufactured by two companies are given. Standards based on these facts were established for vitreous enamel sewer pipe. All technical details are given. W.D.K.

Wet-process leadless cast-iron enamels. B. NIKLEWSKI, JR., AND A. I. ANDREWS. *Jour. Amer. Ceram. Soc.*, **23** [6] 178–85 (1940).

What the jobbing shop must do to handle architectural work. A. C. WEIERICH. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 86–89.—The fundamental problem confronting any manufacturer of porcelain enamel for architectural uses is the adaptation of an inflexible material to an irregular, flexible background. The actual shop operations involved, their control, the manufacture, and inspection are described by W. who advocates that all manufacturers cooperate to the extent of producing only material of the highest quality. F.J.Z.

Work of Committee on Standardization of Tests for Products. W. N. HARRISON. *Proc. Porcelain Enamel Inst. Forum, Fourth Forum, Oct., 1939*, pp. 178–83. F.J.Z.

SEPARATE PUBLICATIONS

Better bathtubs. ANON. *Ind. Bull. of A. D. Little, Inc.*, No. 153 (Dec., 1939).—In the last decade the porcelain enamel industry has shaken off its rule-of-thumb methods and become an exponent of rigid process control and continued research. A peculiarity of the glassy cover coat is that the less of it, the better. A thick coat will chip and is likely to crack under the stress of thermal expansion and bending of the base sheet, but if the cover coats are too thin the dark ground coat will dull the brilliance of the surface color. By the use of opacifying materials and finer grinding of the frit, the thickness of the coats has been reduced 87%. In cleanliness and durability porcelain enamel is outstanding, but in large unbroken walls it is rather monotonous and acts as a mirror, a disadvantage when it is used in illuminated displays. Corrugated finishes have been developed to combat these difficulties

and open new architectural fields to porcelain enamel. Blocks of corrugated-finish enamel may be placed with the corrugations at an angle to each other, breaking the monotony and providing interesting effects which change with the direction of the sunlight. H.E.S.

Color Oxides. CHICAGO VITREOUS ENAMEL PRODUCT CO., Cicero, Ill., 1940. 24 pp., 115 color chips.—Basic information on what color oxides are, how they are made, and how best to handle and apply them is presented. Color chips are grouped according to classification, color combinations, and color comparisons. Methods are described for blending basic oxides to gain the exact shade desired for any porcelain enameled product, whether for heaters, kitchenware, a major appliance, or a giant spectacular sign. The technical aspects of color and color matching have been avoided by using simple language to describe procedures. "Basic" oxides have been separated from the "miscellaneous." The manner of presentation contributes materially to the simplification of color applications and matchings.

Finish on Your Product. FERRO ENAMEL CORP., Cleveland, 1940. 7 pp., 1 chart.—The comparative performances of commercial finishes are presented in tabular form. F.J.Z.

Hairlining of Sheet Steel Enamels. B. J. SWEO. *Ferro Enamel Corp. Tech. Bull.*, No. 5, 20 pp. (April 1, 1940).—Hairlining of enamels can be produced in the laboratory by means of the test devised and described by S. The basic cause of hairlining is a condition of strain established within the piece due to temperature differences present. The presence of a condition of strain on heating rather than on cooling determines whether hairlines will be formed. The number of hairlines formed depends on the ability of the fired coats to withstand cracking when a subsequent coat is fired. The definition of the hairlines is related to the tendency of the undercoat enamel to penetrate into the cracks formed in the upper enamel layers. Ware of a design which hairlined when fired in a box-type furnace was fired without hairlining in a continuous furnace. F.J.Z.

Standard Specifications for Porcelain Enamel Supplies. PORCELAIN ENAMEL & MFG. CO., Baltimore, 1940. 33 pp. —These specifications not only prescribe the grades of material which have been found most suitable in producing high-quality porcelain enamelware but also furnish testing methods by which it is possible, when necessary, to determine whether or not materials purchased meet the specifications. The present specifications, where possible, not only present the pertinent physical and chemical requirements and methods of testing but also briefly outline functions of the product in the enameling operation. The following porcelain enameling supplies are included in the specifications: ammonium carbonate, barium carbonate, bentonite, borax, calcium chloride, clear clay, powdered enameling clays, unrefined clays, cleaner, titanium dioxide, dyes for stainless enamels, Epsom salts, feldspar, flint, magnesium carbonate (light), nepheline-syenite, enamel opacifiers, ceramic coloring oxides, zinc oxide, pickling acid, potash alum, sodium aluminate, sodium nitrite, ammonium alum, and soda ash. The Standard Specifications were prepared by Lyman C. Athy and George H. Spencer-Strong.

Testing of Porcelain Enameling Furnaces. M. J. BOZSIN. *Ferro Enamel Corp. Tech. Bull.*, No. 4, 51 pp. (Feb. 15, 1940).—B. presents a detailed account of the apparatus and methods used in testing porcelain enameling furnaces including the box, continuous fuel fired muffle, radiant tube fired, and electric types. Charts show the temperature gradients on continuous furnaces operating under satisfactory and unsatisfactory conditions. Definite requirements must be met to insure proper and efficient operation. The following analyses can be used as a guide for classifying enamel-furnace atmospheres.

	H_2O (%)	CO_2 (%)	N_2 (%)	O_2 (%)
Good	1.32	0.10	78.44	20.14
Fair	2.22	0.32	77.48	19.98
Poor	3.10	1.65	76.43	18.82

Temperature conditions in box or continuous furnaces must be as uniform as possible to minimize enamel firing difficulties. Fuel combustion should be regulated to obtain the highest efficiency and thus minimize the cost of operation. The technique described for testing enameling furnaces has been found reliable and is in constant use. Charts and tables are included as guides in the interpretation of the results obtained. F.J.Z.

Test for Acid Resistance of Porcelain Enamels: I, Flatware. PORCELAIN ENAMEL INST., INC., Chicago, 1940. 11 pp. Price 20¢.—A revised edition of the bulletin on acid resistance of porcelain enamels (*Ceram. Abs.*, **17** [4] 136 (1938)) is presented. This revision makes it possible to check the finished porcelain-enameled product by means of a spot test; formerly, it was necessary to cut out a sample and completely immerse it in the solution. The bulletin comprises three sections: (1) commercial test, (2) umpire test, and (3) research test. The general classifications of acid resistance, "AA," "A," "B," etc., remain the same as before. This test covers flatware, i.e., table tops, signs, refrigerator and stove parts, architectural panels, etc. Cooking ware, which has been excluded, will be covered in another bulletin.

PATENTS

Combination cooking vessel. E. W. BLANKENSHIP. U. S. 2,199,687, May 7, 1940 (Nov. 16, 1939).

Enamel lined beer barrel. E. G. NYBERG (A. O. Smith Corp.). U. S. 2,198,315, April 23, 1940 (May 17, 1937).

Firing grate for enameling furnace. KARL BÜRGERMEISTER (W. Wülfingoffene Handelges.). Ger. 684,400, Nov. 9, 1939 (March 4, 1938); VI/48*c*. 7.—The firing grate is constructed in the shape of a pointed triangle whose size can be changed by shifting the point. The firing point is arranged on one end of a leg of the triangle; on the other end is a grooved guide in which the adjacent leg of the triangle is movable and in which the adjusted position is fixed. D.A.B.

Opacifier for vitreous enamels. W. J. HARSHAW AND W. D. STILLWELL (Harshaw Chemical Co.). U. S. 2,199,794, May 7, 1940 (Sept. 15, 1938).—A mill addition opacifier for vitreous enamels is a calcination product and contains CaO, Sb_2O_5, TiO_2, and CaF_2.

Opacifier for vitreous enamels. W. J. HARSHAW AND W. D. STILLWELL (Harshaw Chemical Co.). U. S. 2,200,170, May 7, 1940 (Sept. 15, 1938; Nov. 1, 1939).—In making a vitreous enamel, firing together an oxide of antimony, available fluorine material, an oxide from the group consisting of titanium and zirconium, an oxide of a base-forming metal, and an oxidizing agent, mixing the product in a mill charge with enamel frit, and grinding.

Vitreous enameled article. A. L. MATTHES. U. S. 2,199,804, May 7, 1940 (Aug. 10, 1938).—A vitreous enameled article embodies a ferrous base formed of an alloy comprising approximately carbon 0.03, manganese 0.10, sulfur 0.025, silicon 0.007, nickel 2.00, and copper 1.00%, with iron including impurities to make 100%, and has a continuous fused enamel coating on its surface.

Glass

All-glass ball valve stirrer. SILVESTER LIOTTA. *Ind. Eng. Chem., Anal. Ed.*, **12** [3] 173 (1940).—Details of construction are given. Illustrated. F.G.H.

All-glass still with automatic float feed. GEORGE F. LIEBIG, JR. *Ind. Eng. Chem., Anal. Ed.*, **12** [3] 174 (1940).—Details of construction are given. Illustrated. F.G.H.

Brief classification of tinted lenses. E. J. CRUNDALL. *Optician*, **97** [2507*a*] 11 (1939).—Most tinted lenses can be classified into five categories of absorptive lenses. M.B.H.

Calculating batches and glass composition from theoretical values. ANON. *Sprechsaal*, **72** [28] 370–71 (1939).—The article "Simplifying the calculation of batches and

glass composition by tables with conversion factors" (*Ceram. Abs.*, **18** [7] 180 (1939)) is discussed. Although examples are given to show the uncertainty of some of the theoretical values for certain components because of variations in raw materials and working conditions, the tables can be used for easily computed bases with sufficient exactness. M.V.C.

Control for luminous-flame firing in glass furnaces. F. G. SCHWALBE. *Jour. Amer. Ceram. Soc.*, **23** [6] 173–78 (1940).

Decoration of glass by means of enamels and fused colors. O. HERFURTH. *Diamant*, **61** [11] 105; [12] 117; [14] 135; [19] 185 (1939); *Jour. Soc. Glass Tech.*, **23** [100] 380A (1939).—High-silica glasses cannot be used for enameling because of their low expansion compared with that of enamels and fused colors. The surface of such glasses lacks the requisite reaction capacity for taking on enamel, which usually shows bulgings, scalings, etc. Microscopic examination of thin sections of a suitable low-silica glass properly enameled shows very clearly the reaction effect between glass and enamel. This is really a reciprocal action as a result of which parts of the glass become merged into the enamel and parts of the enamel into the glass, forming an adhesive layer or bond between the two. Successful results depend upon the perfect formation of this intermediate layer, which tends to compensate the differences in expansion between the two components. In actual practice a perfect balance is undesirable. It is better to have the layer of glaze or enamel, after cooling, under compression strain, since it is estimated that its compression strength is 10 to 15 times as great as its tensile strength. Accordingly, success depends upon the enamel having a lower heat expansion than that of the base glass. Enamel at a firing temperature of 550° to 580° extracts about 30% of its own weight of silica from the base glass without undergoing the slightest alteration in appearance. This extraction of silica is absolutely necessary in order to harden the surface of the enamel and render it durable. Surface decoration of glass can be classified into six groups: (1) opaque enamel, (2) transparent enamel, (3) fused glass colors, (4) glass luster, (5) noble-metal preparations, and (6) ice crystals. For successful results in all of these classes it is essential to have the materials of a suitable grain size, to apply them uniformly to the glassware, and to have a thorough knowledge of their melting temperatures and perfect control of the requisite firing conditions in the kiln. It is important to know whether the color substances are affected by oxidizing or reducing atmosphere during the firing process. Some color substances, especially black and red, are liable to turn out in various shades if the firing conditions are not maintained constant. Overfiring has a tendency to create "boil" in the glaze and consequently produce blisters and pock marking in the finished article. Since so much depends upon the maintenance of a correct and uniform temperature, it is advisable and economical to invest in some form of reliable thermostat control. The decorative medium may be applied by a paint brush, by compressed air spray pistol, by transfer paper or lithographic methods, or by dusting the dry powder upon a prepared gummed surface.

Education in the glass industry. ANON. *Glashütte*, **69** [33] 561–62 (1939).—The Board of Professional and Technical Education of the DAF, Berlin-Zehlendorf, has issued a new educational guide for apprentices in the stone, clay, ceramics, and glass industries which is similar to the guides used successfully in other industries. The book contains instructions for its use; an outline of each week's study of processes, machines, materials, and their use; space for students' entries of observations made; the results of their practical experience; and sketches of machines, etc. The apprentices' work is supervised and checked regularly by instructors. M.V.C.

Glass founding practice. I. M. K. SEN. *Indian Ceramics*, **1** [4] 129–32 (1938).—Practical notes are given. A.P.S.

Glass measurements of Abbe and his first polyope objective. H. BOEGEHOLD. *Forsch. Geschichte Optik*, **3** [1] 1–15 (1939).—On the basis of complete data and computations contained in the notebooks of Abbe, B. describes the whole development of microscope objective lenses and checks some of the calculations with modern means. The term "polyope objectives" is used for objectives with liquid lenses; a detailed description is given of such lenses of 6.3 mm. focal length, aperture 0.829 (= 112°). A mixture of 7 cassia oil and 1 aniseed oil was used as liquid; tables of refractive indices for these oils are given. Thirteen references. M.H.

Glass. Why foreign ware is cheaper than English ware. SVEN FOGELBERG. *Pottery Gaz.*, **63** [729] 375–79 (1938). L.S.

Glass tank at half capacity need not lower efficiency. THOMAS B. HART. *Ceram. Ind.*, **34** [5] 58 (1940).—H. offers glass-tank design as a practical short cut to profitable retrenchment. The furnace, designed to produce 50 to 60 tons of glassware daily, is modified to be efficiently operated at 30 to 40 tons daily. To reduce the refining end of the tank, a triangular breast wall is installed. The doghouse is relocated, the firing port is reduced, and a bulkhead is built to reduce the checker-chamber size. Feeders and machines remain in their original positions. A covered bridge wall may be run through the center of the tank to provide for a two-color operation. Illustrated. L.M.C.

Heat gain through glass blocks by solar radiation and transmittance. F. C. HOUGHTEN, DAVID SHORE, H. T. OLSON, AND BURT GUNST. *Heating, Piping & Air Conditioning*, **12** [4] 264–70 (1940).—A series of experiments conducted at the Pittsburgh Station of the U. S. Bureau of Mines by the American Society of Heating and Ventilating Engineers is described. The results of one year's work are presented graphically. 11 figures. J.L.G.

Improving sheet glass. F. J. W. *Diamant*, **61** [21] 206 (1939); *Jour. Soc. Glass Tech.*, **23** [100] 372A (1939).—Small pieces of sheet glass (colored, opal, and silvered) can be used profitably by roughening them on one side with a film of sand or glass powder applied to them when slightly softened by heat. The pieces are then fitted together with the rough surfaces embedded in cement or plaster of Paris, forming a mosaic which is then fired until the glass sections become softened and fuse to each other. A certain type of blown sheet is made to simulate the veining of marble by imposing colored glass threads. Cut panes of this material have an uneven surface, giving an imperfect fitting into window frames. Sheet glass of this variety is enhanced in value by providing it with a smooth even border for secure framing. A combination of flattening kiln and casting table has been devised for the production of double sheet glass. The cylinder of blown sheet is flattened on a casting table contained within a heated chamber and situated beneath plate-casting rollers which may be either smooth or patterned. A thick double sheet is thus obtained, one side of which consists of thin blown sheet, eliminating the necessity for grinding and polishing. By this system a variety of combinations of colorless and colored thick plates can be produced. An adaptation of the same method, using Klischee rollers, results in the colored flashing sheet being embedded to varying depths in the thick plate. Subsequent grinding shows up the desired design in color on a plain background.

Invisible glass. ANON. *Optician*, **97** [2500] 42 (1939).—A general survey is given of recent work in America to eliminate surface reflections in optical glass and increase light transmission. See "No reflection," this issue, p. 160. M.B.H.

Low-resistance glass electrode. W. C. JOHNSON. *Chem. & Ind.*, **58** [24] 573–74 (1939).—Glass electrodes ordinarily used for the determination of hydrogen-ion concentration introduce high resistance in the electric circuit. A low-resistance electrode has been achieved by increasing the glass surface rather than by reducing the thickness to a point of extreme fragility. The electrode consists of a bundle of glass tubes each about 1 mm. in diameter and 0.05 to 0.1 mm. in wall thickness, drawn from Corning 015 glass and sealed at one end. The tubes are sealed together near their open ends by means of a cement of high electrical insulation and then sealed to a glass adapter tube. The tubes are filled with a suitable reference fluid by covering

their upper ends with the fluid, evacuating, and then releasing the vacuum. An electrode constructed of 25 tubes of 12 cm. immersion gives a glass surface approximately 35 times greater than that of a glass bulb 1 cm. in diameter. The electrical resistance of such an electrode is between 1 and 2 megohms. Only 10 ml. of sample are required for a determination. The construction of various electrodes and a convenient form of calomel half element are illustrated and described. G.R.S.

Making artificial eyes. STEER WARDMAN AND REGINALD STURGEON. *Optician*, **97** [2511] 259–64 (1939).—Materials used in making glass eyes are described, including white glass for the sclera, more than nine colored glasses for the iris, ruby red for veining, black for the pupil, and clear glass for the cornea. The melting procedure for obtaining glasses of uniform color and expansion is given. The authors claim that soda glass is superior to lead glass in this field and describe a test showing the extent of the attack of the lachrymal secretion in the eye socket on both types of glass. M.B.H.

Marbled and figured glass. F. J. W. *Diamant*, **61** [17] 165 (1939); *Jour. Soc. Glass Tech.*, **23** [100] 353A (1939).—According to a Leipzig process for the manufacture of multicolored, marbled, or veined sheet glass, a pot of ordinary colorless glass is melted, stirred, and refined, and its temperature is lowered to reduce fluidity. A number of different colored glass rods, 6 to 10 mm. in diameter and 40 to 50 mm. long, are then stuck into the melt. The rods soften but do not diffuse entirely in the metal. They form different colored threads or veins which, on subsequent working of the glass, produce a most effective graining or marbling. Opal glass of this variety has a wide application as table tops and for wall and ceiling linings. Another method of producing variegated grained glass depends largely upon the manipulative skill of the glass-blower. Any glass is used as a base, clear, opaque, or colored. After proper marvering, the gathering is sprinkled with various colors of powdered fusible glass, either through a sieve or blown on by a blast of air. The gathering is then reheated and blown to produce fancy-colored grained glassware. The production of clear or colored translucent designs upon mat glass is effected by depicting the design with a film of thick oil upon the mat glass surface. Finely powdered fusible glass, colorless or colored as desired, is then sprinkled on the prepared oil surface. On firing in a muffle furnace at a controlled temperature below the softening point of the mat-glass base but sufficient to flux the fusible glass powder, the resultant fired glass plate shows a translucent design on a mat surface. The applied powder consists of suitable mixtures of borax, litharge, quartz, and granulated soft glass of the requisite color.

Mechanical device for the rapid estimation of the constants of a lens system. ERIC J. IRONS. *Proc. Phys. Soc.* [London], **52**, 184–86 (1940). L.E.T.

Modern absorption glass. W. E. HARDY. *Optician*, **97** [2507*a*] 6 (1939).—H. discusses the history, contents, absorptions, and types and special purpose glasses. Transmission curves of some protective glasses are given. M.B.H.

No reflection. ANON. *Ind. Bull. of A. D. Little, Inc.*, No. 144 (Feb., 1939).—The Massachusetts Institute of Technology and the General Electric Research Laboratories simultaneously announced the discovery of materials which could be put on glass to neutralize its reflection and increase the transmission of light through it. Films of metallic fluorides such as sodium, calcium, magnesium, or lithium fluoride, deposited in a thickness about one-quarter of the wave length of a ray of green light in the visible spectrum, are useful. The material used by the General Electric Co. is a soap film several molecules thick. Reflection may be increased rather than decreased by a change in the refractive index of the film applied to the glass; light transmission is cut down and by reflection the glass may be made to scintillate brilliantly. Applications have been made in high-grade optical instruments, and nonreflecting store windows, mirrors, show cases, and automobile windshields are in prospect. See "Glareless . . . ," *Ceram. Abs.*, **18** [5] 124 (1939); "Invisible . . . ," *ibid.*, [9] 239; this issue, p. 159. H.E.S.

Optically ground. C. R. RENNICE. *Optician*, **97** [2508] 205 (1939).—The imperfections of cheap molded or blown sunglasses are contrasted with the good qualities of optically ground and polished glass. M.B.H.

Performance of glass insulators and comparisons with porcelain. ANON. *Brit. Elec. & Allied Inds. Research Assn. Rept.*, U/T 16; abstracted in *Electrician*, **124** [3230] 321 (1940).—Separate investigations are summarized which, owing to their diverse nature, are described in self-contained sections. Part 1 deals with the effect of power arcs which may develop as a result of a flash over and is confined to suspension insulators. Part 2 indicates the differential heating which might occur under the sun's radiation and which in turn might lead to mechanical stresses and the possibility of fracture. In Part 3 the hazards from stone-throwing are examined, and the impact resistance of insulators is determined from this point of view. Part 4 gives impulse electric strengths of porcelain and glass from which the possibility of puncture due to surges can be estimated. Part 5 deals with some service experience on the behavior of glass insulators in humid and polluted atmospheres. In general, it is aimed to estimate the security of insulators with respect to conditions of service which are not directly related to the standard tests. The tests proved that for toughened glass insulators the minimum completely controlled current that will cause rupture is greater than that reached for porcelain insulators. It was noted that when the toughened glass units failed they were completely shattered, while porcelain units were cracked but remained intact so that a faulty insulator might remain undetected after arcing. In sunlight, porcelain reached 48°C. for white and 70°C. for brown; glass reached 52°C. Clean glass insulators are not subject to thermal stresses to the same extent as brown porcelain insulators. Tests with frequent blows made it seem probable that a porcelain insulator exposed to frequent stone-throwing was more likely to retain the line in service than a glass insulator exposed to similar conditions. Toughened glass might be more resistant to glancing blows, but this depended on the shape of the insulator. The performance of glass insulators in humid and polluted atmospheres is not inferior to that of porcelain units of the same shape. In general, there appears to be little difference in the surface characteristics of insulators made of glass and porcelain. H.K.R.

Possible developments in etching technique. F. J. W. *Diamant*, **61** [13] 125 (1939); *Jour. Soc. Glass Tech.*, **23** [100] 381A (1939).—In the production of colored design in high relief, the general practice was to make up a simple mixture of dry fluorides with some form of adhesive or cement. The results were never satisfactory, the etching color being too faintly imprinted. Progress has been made by dissolving the etching color in a saturated solution of ammonium fluoride in concentrated hydrofluoric acid and mixing this with magnesium carbonate and dextrin. The process requires only half an hour. Apart from cheapening the production costs, it gives a much stronger and sharper etching. An American innovation involves the melting of equal parts of sodium fluoride and calcined soda and grinding the melt to a fine powder before mixing it with the other etching materials. This method is claimed to effect a saving of 25% besides producing a perfectly uniform mat etching over the entire surface. A method originating in Bavaria concerns the production of striped mat and clear glass by immersion in a bath of concentrated HF and H_2SO_4, so that the bubbles forming on the glass rise up parallel to the surface, resulting in unetched lines. Retarding the rise of the gas bubbles by varnish strips greatly enhances the effect. In Thuringia the scope of ornamental etching has been widened by the use of a sharp cutting steel tool somewhat similar to a cyclostyle pen. Another process, also of Bavarian origin, relates to the production of "crystallized" or coarse-grained etching of inscriptions on glass plates, in order to create a self-reflecting transparency. The prepared glass plate is immersed in the etching fluid in horizontal position, prepared side down-

ward, to the depth of half the glass thickness. The evolved gases are compelled to collect in a space between the glass and the acid surface, thereby effecting a crystal-like or coarse-grained etching. Nonuniform etching, known as "flake matting," is produced in two stages. The acidity of an acid potassium fluoride silk mat bath of average concentration is increased by 10% of free HF. Flake etching is then shown as roughened patches on the already fine mat glass. Subsequent color grinding results in a greater intensity of color on the rough spots. By color grinding of the other surface with a different color, a marble effect can be produced.

Practical etching of glass. WALTER MEYER. *Seifensieder-Ztg.*, **65**, 832–34, 851–53, 872–73, 892 (1938); abstracted in *Chem. Zentr.*, **1939, I**, 2847.—Recipes are given for the preparation of matting acids, glass-etching ink and marking liquids, mat etching paste, dry etching salts, etching colors, lacquers, and border and edge waxes and some nonetching, colorlike preparations for giving mat surfaces. The application and action of these products and of sand etching are reviewed. M.V.C.

Jesse Ramsden. HENRY C. KING. *Optician*, **97** [2510] 237–41 (1939).—K. describes the life and works of this great lens and optical-instrument maker. M.B.H.

Repair and construction of laboratory glassware. JOSEPH J. SULLIVAN. *Rept. New England Assn. Chem. Teachers*, **41**, 22–26 (1939); *Chem. Abs.*, **34**, 1209 (1940).—Certain fundamental operations in glassworking are described, and literature references are given.

Rhodium mirrors for scientific purposes. ANON. *Optician*, **98** [2541] 296 (1940).—An ordinary type mirror is useless for scientific purposes because the thickness of the glass in front of the reflecting surfaces forms unwanted images. Newer methods of mirror backing, including the use of aluminum, platinum, palladium, and rhodium, are described. Rhodium is claimed to withstand physical and chemical action better than any other metal tried. M.B.H.

Safety glass. ANON. *Optician*, **97** [2521] 436 (1939).—The history of safety glass is surveyed up to the present use of polyvinyl acetal resin as a bonding agent. M.B.H.

Safety-glass manufacture. J. ZEELANDER. *Mech. World & Eng. Record*, **106** [2743] 85–86 (1939).—A flow-sheet is accompanied by explanations of the consecutive steps in the manufacture of safety glass. F.E.S.

Sample of Faraday glass of the Jena collection for the history of optics. M. v. ROHR. *Forsch. Geschichte Optik*, **3** [1] 18–20 (1939).—A piece of glass was recently discovered which could be traced to Faraday; it is a sample of a heavy glass, probably a dense borate-lead glass. Refractive index and other measurements of the sample agree well with those of other known pieces of glasses with which Faraday experimented. M.H.

Sealing platinum to Pyrex brand glass. E. WICHERS AND C. P. SAYLOR. *Rev. Sci. Instruments*, **10** [9] 245–50 (1939).—The thermal expansion of platinum is considerably greater than that of Pyrex brand glass. When an attempt is made to seal a platinum wire to this glass, therefore, the metal shrinks more than the glass when the newly made seal is cooled. This differential shrinkage sometimes causes the metal to pull away from the glass, but often the bond is strong enough to cause internal cracking of the glass rather than separation at the boundary. Since such a strong adhesive force exists between the two materials, satisfactory sealing would be expected if the shrinkage forces were made smaller than the force necessary to break the glass or to pull the metal away from it. It seemed possible to do this by using a platinum tube rather than a wire or rod. By selecting a tube with a suitable ratio of diameter to wall thickness, its resistance to stretching could be made smaller than the force required to cause failure of the seal. Experiments are described in which the limiting relations of diameter to wall thickness of platinum and glass for satisfactory tubular seals are estimated. The construction, examination, and tests of the seals are discussed and illustrated. H.E.S.

Sodium fluosilicate as opacifier in opaque glasses. F. H. ZSCHACKE. *Sprechsaal*, **72** [50] 583–84; [51] 591–92 (1939).—By a series of melts Z. found that well-opacified glasses with a pure white color and high luster can be obtained with sodium fluosilicate, but he recommends always introducing a part of the fluorine in the form of fluorspar. Alumina in the form of kaolin disturbs the opacification of glasses containing fluorine, while feldspar can improve or impair opacification and color depending on the other ingredients present in the batch. In glasses free from alumina, antimony oxide greatly improves color and opacification. In melts of glasses opacified with fluorine, the addition of too much lime must be guarded against, since lime in certain quantities affects opacification. Zinc oxide improves opacification. The action of barium oxide is not uniform: as a substitute for calcium oxide, it improves opacification and coloring. The replacement of cryolite by sodium fluosilicate need not always impair opacification, even if 1 part sodium fluosilicate for 1 part cryolite is used; such substitution in the tests described improved opacification and color. See *Ceram. Abs.*, **19** [5] 112 (1940). M.V.C.

Suggested improvement in artificial eye making. REGINALD STURGEON. *Optician*, **97** [2519] 403 (1939).—Annealing eyes in a small lehr heated by a medium containing sulfur is said to lower the expansion of the glass at the surface, increase its strength and durability, and lessen the likelihood of strain. S. suggests a new method of decolorizing the edges of artificial eyes which become discolored after some months' wear. The present grinding method affects the fit and causes discomfort. M.B.H.

Suitable size for furnace and machine units. F. H. ZSCHACKE. *Glashütte*, **69**, 401 (1939); *Jour. Soc. Glass Tech.*, **23** [98] 202A (1939).—The economy of a plant depends on the appropriate choice of the size of furnaces and machines. For this reason the practice of driving each machine by its own motor has generally been adopted in Germany. Similar considerations for gas producers have proved to be correct. Several small melting tanks with a volume of 40 tons instead of 200 tons and smaller sized lehrs are preferred.

Volatile acidity of glass. L. BRACALONI. *Boll. Chim.-Farm.*, **78**, 537–41 (1939); *Brit. Chem. & Phys. Abs.-B*, **59** [2] 131 (1940).—The powdered glass sample is heated for 2 min. over a blowpipe in a neutral glass tube with a narrow neck, in which the acid vapor of SiF_4 is condensed. A few drops of a specially prepared solution of Me-red are added.

Welding chrome steel with glass. SCHAD. *Sprechsaal*, **73** [3] 23–24 (1940).—Chrome-steel parts are more easily welded with glass than copper parts because the expansion coefficient of chrome-steel alloys lies in the same interval as that of alkali-lime soft glass. Some of the uses of glass welding on chrome steel for electrical-discharge apparatus, chemical-reaction equipment, and physicotechnical apparatus are illustrated, and the welding technique in each case is briefly explained. M.V.C.

Zinc oxide in the glass industry. L. SPRINGER. *Sprechsaal*, **73** [2] 16–17 (1940).—Two zinc oxides examined for their serviceability in the production of glass, especially for their behavior during fusion, coloring, tendency toward devitrification, and effect on the chemical resistance of the fused glaze, were found satisfactory. The results of the tests are as follows: (*1*) *Fusibility and Firing:* If lime or baryta are replaced by large quantities of zinc oxide, the fusibility and especially the fining are no worse; in many cases they are improved, especially when lime is entirely replaced by zinc oxide. When lead oxide is replaced by zinc oxide, the fusibility is no worse than that of pure lead glasses. (*2*) *Color:* If oxidizing agents such as saltpeter and arsenic are present, no difference can be noted in color. (*3*) *Devitrification:* The tendency of zinc oxide toward devitrification is not as marked as is often assumed. Up to 9% zinc oxide can be added in lead glass and 8% zinc oxide in lead-free glasses without the appearance of devitrification. (*4*) *Chemical resistivity:* In all the cases studied, glasses containing zinc oxide were found to have a better chemical resistivity than glasses without zinc oxide. M.V.C.

SEPARATE PUBLICATIONS

Glasses, gauge: flat (plain and reflex) (for pressures of 125 pounds and over). *U. S. Federal Specification*, DD-G-491, June 29, 1939. **Reflex and round, tank (for pressures under 125 pounds).** *Ibid.*, DD-G-496. **Round, boiler (for pressures of 125 pounds and over).** *Ibid.*, DD-G-511. Supt. of Documents, Govt. Printing Office, Washington, D. C. Price 5¢ each.

PATENTS

Annealing lehr and method of annealing glass articles. ORIE SHACKELFORD. U. S. 2,197,440, April 16, 1940 (March 16, 1937).

Apparatus for assembling the parts of closure clamping devices. FRANK REDMAN (Hazel-Atlas Glass Co.). U. S. 2,198,740, April 30, 1940 (Sept. 19, 1938).

Apparatus for manufacturing a ground or polished glass band. PILKINGTON BROS., LTD. Fr. 850,474, Feb. 18, 1939. D.A.B.

Apparatus and process for producing base units for hermetically sealed glass casings. CORNING GLASS WORKS. Fr. 850,278, Feb. 14, 1939. D.A.B.

Application of securing means to glass doors. G. F. ERATH (Pittsburgh Corning Corp.). U. S. 2,200,387, May 14, 1940 (July 7, 1938).

Bonded glass fibrous products. N. V. MIJ. TOT BEHEER EN EXPLOITATIE VAN OCTROOIEN. Brit. 519,549, April 10, 1940 (Nov. 4, 1937).

Capsule stopper for bottles, jars, glasses, etc. G. F. M. PEDERSEN (Dansk Crown-Cork Fabrik ved Aage Weybye-Lassen). U. S. 21,433, April 23, 1940 (Sept. 9, 1939); reissue of original 2,133,565, Oct. 18, 1938.

Construction of walls for glassmelting furnaces. L. MELLERSH-JACKSON (Hartford-Empire Co.). Brit. 520,-189, May 1, 1940 (Oct. 12, 1938).

Continual drawing of sheet glass. AMERICAN WINDOW GLASS CO. Ger. 684,579, Nov. 9, 1939 (Dec. 8, 1934); VI/32*a*. 23.01.—While the glass band which is being lifted out is still above the lower limits of its range of expansion, a gaseous agent is brought into contact with the glass upper surface within the drawing chamber near the bulb. The gaseous agent follows a rotating course parallel to the upper glass surface and moves from one edge to the other edge over the width of the glass band. D.A.B.

Desulfurizing lehr gases. R. D. SMITH (Corning Glass Works). U. S. 2,198,745, April 30, 1940 (April 26, 1937).

Double glazing. B. F. HAZELTON, JR., W. P. ZIMMERMAN, AND M. K. HOLMES (Owens-Illinois Glass Co.). U. S. 2,198,578, April 23, 1940 (Nov. 6, 1935; renewed Aug. 2, 1938).

Facing unit. FRANK CLARKE (Pittsburgh Plate Glass Co.). U. S. 2,200,382, May 14, 1940 (March 8, 1938).

Feeder for glass furnaces. J. FERGUSON. Brit. 519,586, April 10, 1940 (Sept. 23, 1938).

Furnace for heating the ends of rods and tubes. R. A. BEDFORD. Can. 387,972, April 16, 1940 (Oct. 1, 1937). G.M.H.

Glass article manufacturing machine. T. F. PEARSON (Crown Cork & Seal Co., Inc.). Can. 388,523, May 7, 1940 (June 19, 1937). G.M.H.

Glass-cleaning fluid and the manufacture thereof. F. L. BISHOP, JR. (American Window Glass Co.). U. S. 2,200,354, May 14, 1940 (Jan. 24, 1936; April 12, 1939).—A process for the manufacture of a fluid for cleaning glass sheets to be used in the manufacture of laminated glass consists in heating an ether of the group consisting of dichloroethyl ether and chlor-ethoxy-chlor-ethyl ether together with a metal of the group consisting of ferrous metals, tin, and aluminum to approximately the boiling point, supplying additional heat sufficient to cause the liquid to boil for a period of approximately 3 hr., and thereafter permitting the liquid to cool.

Glass composition for the production of glass fibers. N. V. MIJ. TOT BEHEER EN EXPLOITATIE VAN OCTROOIEN. Brit. 520,247, May 1, 1940 (Dec. 30, 1937).

Glass-cutting apparatus. B. F. ANDERSON (Libbey-Owens-Ford Glass Co.). U. S. 2,200,975, May 14, 1940 (July 1, 1938).

Glass-fabrication process and mold. R. W. MOORE (General Electric Co.). U. S. 2,201,049, May 14, 1940 (Oct. 13, 1939).

Glass tempering apparatus. LEWIS JEX-BLAKE AND JAMES HEATON (Pilkington Bros., Ltd.). Can. 388,415, April 30, 1940 (April 18, 1939). G.M.H.

Glass tubing tempering apparatus. KENNETH STRATTON (Corning Glass Works). Can. 388,522, May 7, 1940 (Jan. 13, 1939; in U. S. March 22, 1938). G.M.H.

Glassware forming apparatus. A. E. BROWN (Owens-Illinois Glass Co.). U. S. 2,199,356, April 30, 1940 (April 16, 1937).

Glassware forming method and apparatus. S. E. WINDER (Crown Cork & Seal Co., Inc.). U. S. 2,198,750, April 30, 1940 (June 23, 1937).

Glassware molding machine. T. F. PEARSON (Crown Cork & Seal Co., Inc.). Can. 388,383, April 30, 1940 (Sept. 15, 1936). G.M.H.

Heating plates of glass for tempering. L. J.-B. FORBES (American Securit Co.). U. S. 2,198,622, April 30, 1940 (May 26, 1936).

Hermetically sealing vitreous or ceramic vessels. BRITISH THOMSON-HOUSTON CO., LTD., W. J. SCOTT, AND W. T. COWHIG. Brit. 519,355, April 3, 1940 (Oct. 15, 1938).

Insulating and weather-resistant material. GAMES SLAYTER (Owens-Corning Fiberglas Corp.). Can. 388,560, May 7, 1940 (Dec. 2, 1937; in U. S. Dec. 30, 1936). G.M.H.

Insulator. J. T. LITTLETON (Corning Glass Works). U. S. 2,198,734, April 30, 1940 (Jan. 31, 1936).

Laminated safety glass. J. D. RYAN AND J. D. GWYN (Libbey-Owens-Ford Glass Co.). U. S. 2,200,969, May 14, 1940 (Dec. 31, 1936).

Lehr belt and method of making. ORIE SHACKELFORD. U. S. 2,199,529, May 7, 1940 (Oct. 20, 1936).

Light-directing glassware. GENERAL ELECTRIC CO., LTD., AND J. G. CHRISTOPHER. Brit. 519,484, April 10, 1940 (Oct. 19, 1938).

Light-transmitting structure. J. O. CHERTKOF. U. S. 2,198,450, April 23, 1940 (Aug. 30, 1939).—A light transmitting structure comprises a plurality of rows of glass blocks.

Machine and process for manufacturing glass vessels. J. DICHTER. Fr. 850,508, Feb. 18, 1939. D.A.B.

Manufacture of fluorescent lamps. C. F. SWINEHART AND H. C. FROELICH (Harshaw Chemical Co.). U. S. 2,200,221, May 7, 1940 (June 5, 1939).

Manufacture and treatment of glass products. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST. GOBAIN, CHAUNY & CIREY. Fr. 850,-272, Feb. 14, 1939. D.A.B.

Means for and method of cooling glass tank walls. A. T. UNDERWOOD (Hartford-Empire Co.). U. S. 2,199,355, April 30, 1940 (June 17, 1937).

Means for and method of removing cracks from a sheet of glass being drawn. A. E. SPINASSE. U. S. 2,197,811, April 23, 1940 (Jan. 12, 1922; renewed Oct. 1, 1935).

Metal-to-glass seal. LYNN GOODALE (Federal Telegraph Co.). U. S. 2,198,769, April 30, 1940 (July 12, 1938).

Method and apparatus for circulating glass. A. E. A. S. CORNELIUS (Crown Cork & Seal Co., Inc.). U. S. 2,198,304, April 23, 1940 (Sept. 26, 1936).

Method and apparatus for forming and feeding gobs of glass. N. R SALSKOV-IVERSEN (Crown Cork & Seal Co., Inc.). U. S. 2,198,742, April 30, 1940 (Nov. 2, 1936).

Method and apparatus for making tubing blanks. W. H. SAID (Corning Glass Works). U. S. 2,198,741, April 30, 1940 (Nov. 23, 1936).

Method and machine for forming ampoules. JAKOB DICHTER. U. S. 2,199,332, April 30, 1940 (July 3, 1936).

Process and apparatus for tempering glass. HAROLD PERRY AND A. W. GROTEFELD (Gilt Edge Safety Glass, Ltd.). U. S. 2,199,511, May 7, 1940 (Sept. 30, 1935).

Purifying gases. P. M. SCHUFTAN. U. S. 2,198,743, April 30, 1940 (Jan. 4, 1938).

Refractory glass. J. H. PARTRIDGE (General Electric Co.). U. S. 2,199,856, May 7, 1940 (Nov. 10, 1936).—A glass having a softening point not less than 1000°C. and capable of being founded at a temperature of 1600°C. consists of 60 to 70 silica, 25 to 35 alumina, 6 to 11 lime, and 1 to 6% of material from the group consisting of magnesia, baryta, zinc oxide, and thoria and contains substantially no other constituents.

Tanks for molten glass. PILKINGTON BROS., LTD., AND J. GASKELL. Brit. 519,204, April 3, 1940 (Sept. 17, 1938).

Tempering apparatus. A. W. WEBER (Corning Glass Works). U. S. 2,198,749, April 30, 1940 (May 21, 1938).

Tempering glass. C. J. PHILLIPS (Corning Glass Works). U. S. 2,198,739, April 30, 1940 (Dec. 28, 1936).—(1) The method of tempering glassware includes heating it to a temperature lying between its strain and softening temperatures and chilling it in a liquid bath having a chilling power lying between the values $\log (H \times 10^6) = 4.00 + 0.003T$ and $\log (H \times 10^6) = 2.50 + 0.003T$ where T is the temperature of the chilling bath in degrees Centigrade. (6) The method of tempering glassware comprises heating it to a temperature between its strain and softening temperatures and chilling it in a bath having a temperature lower than the strain temperature of the glass, the bath comprising 1:2:4 trichlorbenzine.

Treating glass articles. E. C. LIEBIG AND J. F. HYDE (Corning Glass Works). U. S. 2,198,733, April 30, 1940 (Dec. 19, 1936).—The method of treating a glass article containing an alkali metal includes passing a direct electric current through the glass from an electrolyte in contact therewith consisting of a molten inorganic salt containing ions of a metal of the first periodic group other than the alkali metal of the glass, the glass and the salt being heated to a temperature between the strain point and the softening point of the glass whereby the alkali metal of the glass is replaced by the metal of the first periodic group.

Treatment of woven glass fabric. G. M. DE JONG. Brit. 519,567, April 10, 1940 (Jan. 26, 1939).

Vitreous article manufacture. GAMES SLAYTER (Owens-Illinois Glass Co.). Can. 387,926, April 9, 1940 (Sept. 18, 1937). G.M.H.

Walls for glassmelting furnaces. HARTFORD-EMPIRE CO. Brit. 520,188, May 1, 1940 (Nov. 4, 1937).

Structural Clay Products

Coordination of dimensions of building materials and equipment. H. M. LAWRENCE AND M. W. ADAMS. *Bull. Amer. Ceram. Soc.*, **19** [5] 200–201 (1940).

Fire resistance of ceramic building materials. H. D. FOSTER. *Brit. Clayworker*, **49** [576] 18–19 (1940). R.A.H.

Plant experiences in the production of sand-lime brick. O. SCHRAMM. *Tonind.-Ztg.*, **63** [35] 407–409 (1939).—S. gives a short description of the manufacture of sand-lime brick with emphasis on possible difficulties. W.K.

Role of absorption in the application of mortars, renderings, and plasters to brickwork. L. W. BURRIDGE. *Trans. Brit. Ceram. Soc.*, **39** [3] 71–83 (1940).—On the basis of "working absorption" or "suction" of building brick, B. discusses (1) building mortars used to join brick together to form brickwork, (2) rendering mortars used as external finishes to brickwork, and (3) plasters applied to the interior faces of brickwork. R.A.H.

PATENTS

Apparatus for making tile from clay products. R. M. FLORES (H. E. Ellis). U. S. 2,200,270, May 14, 1940 (Nov. 29, 1937).

Building block. C. F. TEFFT (Claycraft Co.). U. S. 2,198,399, April 23, 1940 (July 19, 1939).

Building block. S. W. WILLIAMSON. U. S. 2,198,688, April 30, 1940 (Oct. 19, 1937).—An article of manufacture comprises a hollow block having a plurality of longitudinally disposed rows of air cells, the air cells of one row being staggered relatively to the air cells of the other row, and facing-securing keyways between the air cells of one of the rows.

Structural block and wall construction. D. M. MUIRHEAD. U. S. 2,198,011, April 23, 1940 (Nov. 3, 1938).

Refractories

Beryllium oxide refractories: II. H. E. WHITE, R. M. SHREMP, AND C. B. SAWYER. *Jour. Amer. Ceram. Soc.*, **23** [6] 157–59 (1940); for Part I see *ibid.*, **22** [6] 185–89 (1939).

Blast-furnace linings: III, Preliminary results of examination of brick from furnaces off for relining. A. T. GREEN, W. HUGILL, AND H. ELLERTON. *Iron & Steel Inst., Special Rept.*, No. 26, pp. 217–32 (1939).—A systematic series of samples was obtained from various zones and positions in the refractory lining of a blast furnace off for relining. Plan and section views of the furnace, showing location of samples, and visual descriptions of the samples are presented. Thin-section studies were made on a number of samples, and information concerning the condition of the working surface is given for each. Alkali determinations were made on portions taken from (1) the working surface shell and incrustation, and (2) the material about 1 in. behind the working face, all zones from top to bottom of the furnace being represented in the sampling. Results indicate that alkali-salt vapors are among the contributory causes of the failure of blast-furnace linings. It is established that at least a portion of these alkalis are present as cyanides, free to distill from the interior to the exterior of the lining and undergo deposition in localized positions of the brickwork. Brief data obtained from two additional plants confirm these observations. The influence of reducing gases is noted in connection with "iron spots," and disintegration due to carbon deposition around these spots is evident. Major disintegration at the top of the furnace has taken place just below the gas outlet. It is suggested that the direction of the gases has an influence in determining the zone of attack and failure. Slag attack becomes distinctly evident about half way up the 80-ft. stack and becomes much more pronounced in the lower zones. Apparent-porosity data are cited to give indications of the extent of surface actions, particularly slagging action. One of the chief consequences of slag attack is a weakening of the material behind the glassy slag layer, resulting in spalling of the brickwork. Evidence of relatively high temperature effects noted in the topmost zones suggests that on occasions temperatures of over 1000°C. have existed within 15 ft. of the top of the furnace, possibly due to the gases selecting paths more by way of the lining than through the burden in the furnace. **IV, Investigation of linings of three blown-out furnaces.** W. WOODHOUSE, W. HUGILL, AND A. T. GREEN. *Ibid.*, pp. 233–94.—Detailed examinations and analyses of three additional furnaces are presented. The most important zone of deterioration was found about 10 to 15 ft. above the bosh. Intense erosion and slag attack were noted at the bosh level. Spalling evidence, disintegration due to carbon deposition around "iron spots," and the effect of alkali-salt vapors substantiate the observations reported in Part III. Zinc sulfide crystals and globules of lead were detected in proximity to areas apparently disintegrated by carbon monoxide action. The role that zinc compounds

and lead play in disintegration was not confirmed. For Parts I–II see *Ceram. Abs.*, **14** [8] 191–92 (1935). P.S.D.

Brick linings for rotary furnaces. C. C. Downie. *Mining Mag.*, **61**, 137–39 (1939).—The first layer of refractory blocks is laid in, and a fire-clay grout is poured over them. An internal wooden pattern keeps the blocks from collapsing. A thicker fire-clay slurry is then applied and fired in with a hand oil burner. If a basic lining is required, fire-clay blocks are put next to the shell, followed by low-grade and then high-grade magnesite. The furnace is fired with oil or pulverized coal; it runs at about 1 r.p.m. When the charge is finished, the slag is run off and the metal tapped. Advantages are as follows: (1) a corrosive slag attacks the entire surface, not on one line; (2) the flame of the burner does not play on the same place; (3) the charge is kept intimately mixed, which causes more rapid reaction and (4) during tapping, the flame is kept on so that the furnace is not allowed to cool. The best refractories are the most economical for this furnace. W.D.F.

Choosing refractories. B. Thomas. *Proc. Staffordshire Iron & Steel Inst.*, **54**, 16–32 (1939).—The choice of refractories depends upon the type of furnace, rate of working, temperature, and cost. T. discusses types of furnaces used in secondary metallurgical processes and the qualities required of the refractories. Ranges of analyses suiting different purposes are given, but T. suggests that physical properties are also important. Microscopic examination is useful. Siliceous brick and silica brick are distinguished, and their separate applications are discussed. The effect of various fuels on a refractory affects the choice of brick. Insulating materials are examined, and the economic limits of their application are indicated. A discussion is included. See *Ceram. Abs.*, **18** [1] 24 (1939). A.B.

Chrome-spinel furnace linings. Anon. *Mech. World & Eng. Record*, **106** [2764] 576 (1939).—Tongued and grooved linings for electric furnaces, made by General Refractories, Ltd., Sheffield, England, are briefly described and illustrated. See "Refractories . . . ," *Ceram. Abs.*, **17** [11] 354 (1938). F.E.S.

Electrically manufactured steels. H. A. Sieveking. *Mech. World & Eng. Record*, **106** [2762] 517; [2765] 606 (1939).—Two types of electric furnaces are used for manufacturing steel, the arc and the high-frequency induction types. Both types and the refractory material used are described. A comparison of the efficiency of the two types shows that the arc furnace is superior to the high-frequency induction type. F.E.S.

Furnace patches. C. C. Collins. *Power Plant Eng.*, **44** [2] 82 (1940).—Air infiltration through cracks in boiler settings can be prevented satisfactorily by the use of a mixture of mineral wool and fire clay made up to a pasty consistency. B.C.R.

Fused magnesia. Burrows Moore. *Trans. Brit. Ceram. Soc.*, **39** [2] 41–51 (1940).—The sources of magnesia and its chemical and physical properties, physicochemical relations, and industrial applications are outlined. R.A.H.

Heat insulation: I. E. T. G. Emery. *Eng. & Boiler House Rev.*, **53** [9] 469 (1940).—In discussing the types of insulation applicable to boiler-house equipment, E. reviews the materials suitable for both low (up to 200°F.) and high temperatures; for high temperatures 85% magnesia, diatomite, and asbestos are most widely used. B.C.R.

Highly refractory chrome-dolomite material and its test in service. I. I. Susidko and E. I. Yudin. *Metallurg*, **14** [10–11] 54–59 (1939).—Dolomite clinker of definite mineralogical composition was obtained from mixtures of dolomite with 5 to 8% quartzite and 3, 5, 10, 15, 18, and 20% chromite. The components were mixed with 8% water and then compressed into briquettes which were dried and then fired for 1 hr. at 1560° to 1580° in an electric furnace. Only those clinkers which had 18 to 20% chromite with the proper proportion of silica were stable. The stable clinker was ground, mixed with water, and compressed into brick in a hydraulic press. The unfired brick were tested both in the laboratory and in large-scale furnaces. Laboratory tests showed a refractoriness of over 1900°. In an electric furnace the brick showed greater stability than chrome-magnesite and magnesite refractories. In an open-hearth furnace they lasted 370 to 720 heats. The compositions of the dolomite, quartzite, and chromite are tabulated. B.Z.K.

Increasing the resistance to corrosion of normal tank-block masses. Adolf Möser. *Sprechsaal*, **73** [1] 2–3 (1940).—Attempts to obtain a tank block resistant to corrosion and the disadvantages of previous solutions on the basis of economy in raw materials and operation are discussed. M. describes a method to further develop masses synthesized in the usual way, which is based on the principle of firing the block at higher temperatures. In this way it is possible to obtain a better bond between the grains and improved homogeneity of the body. The effect of firing on the properties of the block and a series of tests with twelve masses which were fired at high temperatures are described. A general improvement in the properties of the masses was noted. M.V.C.

Natural and artificial marshalite. I. S. Shenderovich. *Litelnoe Delo*, **9** [6] 32–34 (1938); abstracted in *Chem. Zentr.*, **1939, I**, 4376.—The properties of natural Russian marshalite and synthetic marshalite are compared. Refractory mixes were made from both materials and used as a protective layer for steel casting molds. The mixes were composed of 54.8 marshalite, 2.4 bentonite, 6.2 sulfite ester, and 36.5% water. Linings containing synthetic marshalite possessed much greater refractoriness. M.V.C.

Open-hearth bottoms. A. M. Morton. *Steel*, **104** [18] 44, 77 (1939).—A more refractory bottom provides complete drainage of nonferrous as well as ferrous metals and slag from the hearth, thereby reducing the possibility of injurious bottom boils; installation costs, compared with those of conventional bottoms, are also reduced. Savings in installation cost and furnace time total 48.4%. H.E.S.

Refractories in industrial service. W. J. Rees. *Proc. Cleveland Inst. Engrs.*, **1938–39**, No. 3, pp. 87–103; *Jour. Iron & Steel Inst.*, **140** [2] 313A (1939).—R. considers in detail the characteristics of fire-clay, silica, and basic refractories, pointing out the advances which have been made in recent years.

Refractory service in glass furnaces. Report of Committee C-8 on Refractories of the A.S.T.M.: Appendix II, Industrial survey of conditions surrounding refractory service in continuous plate glass and window glass furnaces. *Proc. Amer. Soc. Testing Materials*, **39**, 349–56 (1939); *Ind. Heating*, **6** [9] 831–36; [12] 1171–73 (1939).—A discussion and a survey of actual conditions in glass furnaces, refractories used in different parts, life, and destructive influences are presented. A classification is given in the following table: M.H.

Classification of Refractories for Flat Glass Industry

Furnace parts	Material	Temperature	Slagging action	Abrasion	Spalling	Remarks
Melting chamber Bottom Sides Ends	Highly siliceous hand made, machine-made, or slip-cast block. High-alumina molten cast block	2450° to 3000°F. (1345° to 1650°C.)	Severe	Severe	Slight	Spalling of great importance during heating up

CLASSIFICATION OF REFRACTORIES FOR FLAT GLASS INDUSTRY (*Continued*)

Furnace parts	Material	Temperature	Slagging action	Abrasion	Spalling	Remarks
Doghouse						
Bottom Sides	Same as melting chamber	Up to 2900°F. (1595°C.)	Severe	Severe	Slight	Same as melting chamber
Refining chamber						
Bottom Sides Ends	Same as melting chamber	Up to 2850°F. (1565°C.)	Severe in some furnaces	Slight	Slight	Same as melting chamber
Neck						
Bottom Side	Same as melting chamber	Up to 3000°F. (1650°C.)	Severe	Moderate	Slight	Same as melting chamber
Tank crown	Silica brick	Up to 3000°F. (1650°C.)	Moderate to severe	Severe in some furnaces	Important	
End walls	Silica brick. High-alumina block	Up to 3000°F. (1650°C.)	Moderate to severe	Severe in some furnaces	Unimportant	
Breast walls and plate block	Silica block. High-alumina block. Molten cast block	Up to 3000°F. (1650°C.)	Severe	Severe	Slight	Spalling of plate block very important when replaced during hot repair
Invert arches	Silica shapes	Up to 3000°F. (1650°C.)	Severe	Severe	Important	
Port jambs	Silica block. High-alumina block. Molten cast block	Up to 3000°F. (1650°C.)	Severe	Severe	Slight	
Port sills (plate block)	Silica block. High-alumina block. Molten cast block	Up to 3000°F. (1650°C.)	Severe	Severe	Slight	Same as plate block
Burner block	Fire-clay block. High-alumina block	Up to 3000°F. (1650°C.)	Severe	Severe	Important	Same as plate block
Port seats						
Crown Sides Paving	High heat duty fire-clay brick. High-alumina brick	Up to 3000°F. (1650°C.)	Severe	Severe	Slight	
Port chambers						
Crown Sides Paving	High heat duty fire-clay brick. High-alumina brick	Up to 3000°F. (1650°C.)	Severe	Severe	Slight	
Uptakes	High heat duty fire-clay brick. High-alumina brick	Up to 2900°F. (1595°C.)	Severe	Severe	Slight	
Regenerator chamber						
Crowns Walls	High heat duty fire-clay brick	2500°F. (1370°C.) max.	Severe in upper portion; slight in lower portion	Severe in upper portion	Important	Some limited use of high-alumina brick in crowns
Checkers	High heat duty fire-clay brick. Super duty fire-clay brick	2550°F. (1400°C.) max.	Same as for regenerator chamber	Severe in upper portion	Important	Some use of special magnesite brick
Tunnels (canals)	Intermediate heat duty fire-clay brick	Up to 1400°F. (760°C.)	Unimportant	Unimportant	None	
Stack	Intermediate and moderate heat duty fire-clay brick	Up to 1350°F. (735°C.)	Unimportant	Unimportant	None	
Tuckstones	Silica shapes. High-alumina shapes. Molten cast shapes	Up to 3000°F. (1650°C.)	Severe	Severe	Slight	Watercoolers sometimes replace tuckstones
Cooling chamber						
Bottom Sides	Same as melting chamber	Up to 2650°F. (1455°C.)	Moderate to severe	Moderate	Important	
Superstructure	Silica brick and shapes	Up to 2650°F. (1455°C.)	Slight	None	Important	
Floaters	Siliceous clay parts, handmade and slip-cast	Up to 2650°F. (1455°C.)	Moderate to severe	Unimportant	Important	Requires good transverse strength

Stable chrome-magnesite linings for the sintering zones of rotary cement kilns. V. D. Sidorov. *Tsement*, **6** [3] 14–23 (1939); see "Resistant . . . ," *Ceram. Abs.*, **19** [6] 143 (1940). P.B. & E.S.

Use of refractories in melting copper and copper alloys in an Ajax-Wyatt induction furnace. Seaver H. Booth. *Bull. Amer. Ceram. Soc.*, **19** [5] 171–72 (1940).

BOOK

Refractories for Furnaces, Kilns, Retorts, etc. Chief Raw and Manufactured Materials and the Processes and Machinery Employed in Their Production. Alfred B. Searle. Crosby, Lockwood & Son, Ltd., London. 102 pp. Price 3s 6d. Reviewed in *Brit. Clayworker*, **48** [572] 292–93 (1939). R.A.H.

PATENTS

Application of refractory brick to masonry not requiring mortar. Österreichische Magnesit A.-G. Fr. 850,223, Feb. 11, 1939. D.A.B.

Electric steel furnace. Willy Linder (Koppers Co.). U. S. 2,200,372, May 14, 1940 (May 11, 1938).

Furnace wall support. C. W. Dunlap (Plibrico Jointless Firebrick Co.). Can. 387,950, April 9, 1940 (Dec. 7, 1938; in U. S. Nov. 10, 1938). G.M.H.

Producing aluminum-magnesium silicates. Ludwig Stuckert (Herbert Witzenmann). Ger. 684,941, Nov. 16, 1939 (Nov. 5, 1937); IV*b*/12*i*. 38; addition to Ger. 458,475.—A method for producing aluminum-magnesium silicates comprises fusing a magnesium compound with quartz, aluminum oxide, feldspar, and fluorite according to Ger. 458,475. Instead of magnesium chloride, magnesium salts such as magnesium carbonate, magnesium sulfate, and magnesium oxalate are used which produce MgO readily upon being heated. D.A.B.

Refractory article. F. W. Higgins (Carborundum Co.). Can. 387,887, April 9, 1940 (Dec. 4, 1937; in U. S. March 2, 1937). G.M.H.

Underfired regenerative coke oven. Walter Stäckel (Otto-Wilputte Ovenbouw Mij. N. V.). U. S. 2,199,513, May 7, 1940 (July 7, 1939).

Terra Cotta

Manufacture of flowerpots. V. *Argile*, No. 196, pp. 17, 21; No. 197, pp. 21–25 (1939); No. 198, p. 11 (1940).—V. describes the mechanized production of flowerpots with the Schuster press and their drying and firing. The rapidity and ease of operation of the press and the superiority of the pots over the handmade pots are shown. Any system of drying can be used, and drying can be accelerated without fear of damaging the pots provided the clay has been carefully prepared to form a homogeneous paste. Either intermittent or continuous furnaces can be used for firing. See *Ceram. Abs.*, **18** [7] 186 (1939). M.V.C.

Zinc-vapor glazing of clays: II, Effect of variable lime and alkalis in clays on zinc-vapor glaze colors. C. M. Lampman and H. G. Schurecht. *Jour. Amer. Ceram. Soc.*, **23** [6] 167–70 (1940); For Part I see *ibid.*, **22** [3] 91–95 (1939).

Whiteware

Better ware at lower cost. Anon. *Ceram. Ind.*, **34** [5] 32–33, 54 (1940).—Recent improvements have been made by the Hall China Co., East Liverpool. Labor costs in the batching department have been reduced by a straight line of clay and raw-material bins from which materials are discharged into a traveling weighing batch car. Water is added to the blungers automatically and is measured through a meter. About 80% of the ware is cast. A recirculating casting slip system of copper piping is used, the slip being supplied from a counterweight pump. Two deairing pugmills have been installed for use with the jiggered body and have proved very satisfactory. Most glazes are applied by dipping; a vertical spout is placed in the bottom of a glaze booth, through which a spray of glaze spouts whenever a foot pedal is depressed. Much of the glaze application on standard dinnerware shapes is done automatically by spraying machines. A low-cost homemade drier utilizing plywood has been constructed. Six continuous kilns firing natural gas are used. Ware is placed on silicon carbide slabs in the post and slab type of bird-cage superstructure. Fuel consumption is controlled with great accuracy. A muffled glost kiln uses luminous flame firing for colored ware, almost all of which is single fired. A counterflow electric decorating kiln which has been installed is described. Illustrated. L.M.C.

Evaluation of glaze-fit test methods. W. C. Bell. *Jour. Amer. Ceram. Soc.*, **23** [6] 163–66 (1940).

Modernization of pottery layouts. Anon. *Pottery Gaz.*, **63** [728] 256 (1938).—A completely automatic conveyer system in a pottery plant is described. L.S.

Properties of clay casting slips. George A. Loomis. *Jour. Amer. Ceram. Soc.*, **23** [6] 159–62 (1940).

Tin oxide in ceramic glazes. Ludwig Stuckert. *Sprechsaal*, **73** [2] 13–15; [3] 21–23; [4] 29–31; [5] 37–39; [6] 43–46 (1940).—The chemical and physical processes taking place during the fusion of tin oxide in frits of different compositon are described, and conclusions are drawn for the technical use of tin oxide. The effect of different constituents of the glaze, viz., boric acid, lead oxide, aluminum oxide, alkalis, and auxiliary opacifiers, etc., on the opacification is dealt with. The experiments confirm the data of other authors according to which a large part and sometimes all of the tin oxide may dissolve in the frit. In tests made by S., the tin oxide returned to a greater or lesser degree during cooling and slow hardening or annealing, so that glazes in which the tin oxide vitrified almost entirely may become opaque during annealing. The solidified frits contain tin oxide in the form of a supersaturated solution and are distinguished by a very high viscosity. When the excess tin oxide crystallizes out during "tin oxide devitrification," as the phenomenon is called, the viscosity drops suddenly almost to the numerical value of the initial material without tin oxide. Frits of this kind can contain only small quantities of tin oxide in saturated solution. Viscosity and hardening curves show very clearly that the dissolving process of tin oxide and its reseparating out is a reversible process in lead frits and an irreversible process in alkali frits, i.e., during the melting of the batch the tin oxide separates out almost entirely in the form of opacifying particles in frits with high lead content, while in frits with high alkali content most of the tin oxide remains in solution as alkali stannate. This information would indicate that in alkali frits tin oxide for opacifying should be added to the mill instead of being fused with the batch. The introduction of tin oxide into the fusion improves different properties. Glazes opacified by tin oxide fuse more easily. Fritting tin oxide in other glazes produces a coat free from cracks on the body, whereas the same glaze without tin oxide is netted with cracks. When tin oxide is fritted in the glaze, it affects the coefficient of expansion in such a way that it is better adapted to the body, and the elasticity of the glaze is increased. The chemical resistivity of the glazes is increased, and luster is more permanent. "Tin ashes," prepared differently than tin oxide, give a slightly better opacification with lead stannate made from a lead-tin alloy; the advantage is, however, not great enough to offset the cost and trouble of preparing special tin ash. The addition of common salt, whenever tin oxide is fritted with the batch, is superfluous and has no effect on the opacification and

luster of the finished glaze. Boric acid and lead oxide introduced in place of silica into glazes with a low degree of acidification diminish the opacification which tin oxide produces in such glazes. The similar action on tin oxide opacification of two constituents of glazes with such divergent chemical behavior can easily be explained by the nature of tin oxide as a relatively strong acid. In glazes with a higher degree of acidification, however, a high boric acid content does not have that effect. The replacement of silica by alumina increases the opacification of tin oxide. If other known opacifying agents like ZrO_2 and TiO_2 are introduced into the batch instead of silica, the opacification of tin oxide glazes is increased with zirconium oxide. If a part of the tin oxide is replaced by zirconium oxide in strongly acid fusions, glazes will be obtained which are not only highly opacified but which have a luster superior to fusions containing pure tin oxide. Replacing lead oxide in the "SF" by alkalis greatly reduces opacification. The vitrification of the tin oxide is irreversible here, which results from the continuous rise of the viscosity curves of such highly alkaline frits. In glazes with a higher acidification this injurious action of alkalis on the vitrification of tin oxide occurs and compels the use of another technique. The fields of serviceability for the three basic components ($PbO/BaO/Na_2O$, $PbO/CaO/Na_2O$, and $PbO/ZnO/Na_2O$) in glazes as well as the fields within which the composition of serviceable and unserviceable glazes varies can be represented graphically. The most favorable action of the components on opacification with tin oxide rises in the sequence BaO–CaO–ZnO. A study of the effect of auxiliary opacifying agents, such as fluorspar, cryolite, and bone ash, on tin oxide opacification showed that fluorspar definitely improves opacification. Its presence in a small amount is therefore useful in frits containing tin oxide. Cryolite is neutral in small amounts, and in larger amounts it does not aid in tin oxide opacification. Small amounts of bone ash increase tin oxide opacification but at the expense of the luster of the glaze. Greater caution should be exercised in the use of these auxiliary opacifiers; it is better not to add them to the batch. Small quantities of antimony trioxide and cerium dioxide as auxiliary opacifiers colored the glazes. M.V.C.

Use of North Carolina kaolin in casting bodies. W. H. EARHART. *Bull. Amer. Ceram. Soc.*, **19** [5] 163–68 (1940).

Viewpoints on the production of whiteware glazes free from lead and borax. HEINRICH ROCH. *Sprechsaal*, **73** [7] 54–55 (1940).—In choosing fluxes in lead-free and borax-free glazes, the bases BaO and MgO should not be present in large amounts and it is better to omit BaO entirely. Among the alkalis, CaO and ZnO are the best glaze formers; before the quantity of ZnO is fixed, however, it must be known whether the glaze is only for whiteware or for ware with underglaze decoration. For glazes free from lead and borax, only a relatively higher Al_2O_3-SiO_2 content gives good results; too small a content gives a mat glaze or devitrification, while too large a content raises the fusing temperature and covering power. The alkali content should be introduced in the form of feldspar (Norwegian feldspar is best suited, though some German feldspars with low alumina content and containing Na_2O and K_2O are named); such glazes do not set without kaolin. Lead-free and borax-free glazes fuse and become lustrous only within a very short temperature interval. A satisfactory lead-free and borax-free glaze can be prepared between Seger cone 2*a* and 3*a*; it is much softer than ordinary glazes, but it has a high luster. M.V.C.

SEPARATE PUBLICATION

Nepheline Syenite in Ceramic Ware. C. J. KOENIG. *Ohio State Univ. Eng. Expt. Sta. Bull.*, No. 103, 74 pp. (1939).—Nepheline syenite, which is a ceramic fluxing agent, is an igneous rock made up essentially of nepheline and alkali feldspars. A large deposit at Blue Mountain, Ontario, provided the material for this work. The variation in thermal expansion between crystalline and glassy nepheline syenite is very small. Potash feldspar has a sintering range from cone 02 to 8 or 9; nepheline syenite ranges from cone 08 to 6. At the same cones, bodies with nepheline syenite show less absorption than those with potash feldspar. Nepheline syenite mixed with talc in place of potash feldspar starts to shrink four cones earlier. Nepheline syenite mixed with pyrophyllite acts similarly. Bodies with small percentages of $CaCO_3$ and $MgCO_3$ and with nepheline syenite substituted for potash feldspar shrank five cones earlier. Bodies with finely ground nepheline syenite gave more strength, less sag, more fluxing action, and more shrinkage than bodies with coarser nepheline syenite. Sanitary porcelain bodies showed increased vitrifying action with nepheline syenite substitution, as well as lower absorption, higher shrinkage, high modulus of rupture, and higher pitch when rung. Nepheline syenite permits the use of a lower maturing temperature which saves fuel. Floor and wall tile bodies acted similarly and had a lower thermal expansion. It is possible to flux the more refractory American clays satisfactorily with nepheline syenite. Electrical porcelain bodies showed the same effects on the substitution of nepheline syenite. Structural clay products also showed the same effects, and there is an increase of vitrification which improves the weathering resistance and the general physical properties in service. Nepheline syenite is a good material for introducing alumina and alkali into a glass batch; it melts at a low temperature and is readily incorporated into the melt. A typical opal glass with nepheline syenite melts at a lower temperature, thus saving on fuel and refractories. The glass has the same thermal expansion but softens at a temperature 50°C. lower. Sheet steel porcelain enamels with nepheline syenite are higher in alumina but are no harder; the physical properties are good. Such enamels have excellent adherence, are more easily applied, are lighter in color, and need less cover coat. Fine grinding of nepheline syenite allows its use in larger quantities. W.D.F.

PATENTS

Apparatus for applying glaze. B. A. JEFFERY (Champion Spark Plug Co.). U. S. 2,198,999, April 30, 1940 (May 12, 1937).

Method and apparatus for manufacturing pottery ware. W. J. MILLER. U. S. 2,200,860, May 14, 1940 (Feb. 9, 1935; July 20, 1935).

Spark plug. CHARLES SMITH. Can. 388,001, April 16, 1940 (Dec. 20, 1938). G.M.H.

Spark plugs for internal combustion engines. LODGE PLUGS, LTD., D. TURNER, AND E. L. WILMART. Brit. 520,058, April 24, 1940 (Oct. 25, 1938).

Wiring box. L. H. PECK (Porcelain Products, Inc.). U. S. 2,197,897, April 23, 1940 (July 9, 1938).

Equipment and Apparatus

All glass flowmeter with interchangeable orifices. ANON. *Chem. & Ind.*, **58** [21] 514–15 (1939).—A flowmeter for the control of gases in the study of gaseous reactions is described and illustrated. G.R.S.

Antivibration support for sensitive portable galvanometer. W. S. GORTON. *Bell Lab. Record*, **17** [6] 195–97 (1939).—G. describes a new design for supporting sensitive galvanometers to minimize the disturbing effect of mechanical shock and vibration. The design has been found satisfactory where building vibrations are considered exceptionally bad. Illustrated. P.S.D.

Calculation of particle trajectories. C. E. LAPPLE AND C. B. SHEPHERD. *Ind. Eng. Chem.*, **32** [5] 605–17 (1940).—Equations are developed for calculating the paths taken by bodies or particles undergoing accelerated motion, taking into account the effect of fluid friction. In several cases curves have been prepared to simplify the computation and eliminate graphical integrations. Available ex-

perimental data on particle trajectories show excellent agreement with calculated values. Applications to spray cooling or crystallization, cyclone dust collection performance, classification, dust sampling, and ventilation are presented and discussed, together with illustrative numerical calculations. Illustrated. F.G.H.

Conico-cylindrical viscometer for measuring the viscoelastic characteristics of highly viscous liquids. A. R. Lee and J. B. Warren. *Jour. Sci. Instruments*, **17** [3] 63–67 (1940).—An absolute viscometer of the rotating cylinder type was constructed for use in studying the fundamental flow characteristics of bituminous road binders. Viscosities from 10^3 to 10^9 poises can be accurately measured, and a value for the elastic recovery of the material under known conditions of shear, stress, and temperature can be obtained. 2 figures. J.L.G.

Development of a centrifugal ball mill. W. F. Carey, E. W. Robey, and H. Heywood. *Engineering*, **149** [3874] 378 (1940).—Preliminary work done in an attempt to construct a centrifugal ball mill employing all the advantages of "free crushing", i.e., the crushing of a single layer of particles between metallic surfaces, is described; a sketch is included. Such a mill is believed to have a high operating efficiency. Several engineering difficulties were encountered due to both the large surfaces required for grinding and the difficulty in obtaining a satisfactory radial distribution of the feed. Although no further work is contemplated, the authors believe that a satisfactory machine can be built. B.C.R.

Diffraction apparatus of E. Abbe. A. Köhler. *Forsch. Geschichte Optik*, **3** [2] 26–78 (1940).—K. gives a complete survey of the studies and theory of Abbe on the origin of the picture in the microscope and describes the apparatus, test methods, and experiments used to verify the theory. M.H.

Electric furnace for the micro-Carius determination. Julius A. Kuck and Maurice Griffel. *Ind. Eng. Chem., Anal. Ed.*, **12** [2] 125–26 (1940).—Illustrated. F.G.H.

Electrostatic separations of solids. Foster Fraas and Oliver C. Ralston. *Ind. Eng. Chem.*, **32** [5] 600–604 (1940).—Basic principles and their application in electrostatic separation are discussed. Electrostatic separators are classified according to the electric property of the solid utilized, i.e., conductance, contact potential, dielectric constant, dielectric hysteresis, and pyroelectric polarization. Only the conductance method has been applied to any important extent. The progress of electrostatic separation has been retarded by several factors, particularly the lack of selectivity. Selectivity can be increased by surface cleaning, by preconditioning silicate minerals with hydrogen fluoride gas and basic minerals with organic acids, and by the use of various surface active agents and oils. Although now seldom used, electrostatic separation has diverse applications in the ore dressing, chemical, and food industries. Through mechanical improvements, including better insulation, and a better understanding of principles and limitations, this method is being increasingly used. By utilization of conditioned air, this method and the contact potential method of separation (now under active development by the Bureau of Mines) promise a wider field of usefulness. Illustrated. F.G.H.

Employing photoelectric device to control open-hearth temperature. John Johnson. *Steel*, **104** [2] 49 (1939).—Control of open-hearth temperatures is accomplished by means of an electric eye which is mounted in the walls of the furnace at such an angle that only light from the roof interior is reflected into it. When the inside temperature gets too high and increases the brightness of the roof too much, part of the fuel supply is turned off automatically. The electric eye utilizes a microscopically thin film of rare metal as a "retina." In addition to improving the quality of steel due to elimination of temperature fluctuations, the electric eye control has extended the useful life of the refractory brick linings, making possible 450 to 500 heats in a furnace before shutdowns for repairs are necessary. Illustrated. H.E.S.

Filtration's future. Arthur Wright. *Ind. Eng. Chem.*, **32** [5] 617–21 (1940).—The progress in filtration during the last quarter of a century is primarily due to the establishing of fundamental principles and evaluating the factors influencing filter performance. The future seems bright for better filtrations. The standards of performance will be higher because the designer, the process engineer, and the machine operator appreciate the worth of scientific control. The range of application of filters is increasing, especially for continuous and automatic units. Better flow sheets are obtainable by synchronizing continuous filters with thermostatic control of temperature, dosing with pH regulators, ensuring complete chemical reactions by providing proper retention periods, etc. Perhaps the greatest promise lies in the use of continuous filters for clarification duty. The Oliver precoat filter and the Wright cord filter are showing the way; as low-pressure filters they can handle flocculent precipitates and ensure positive clarity from settlers. The goal of all filter designers is to build filters capable of coping with requirements of chemical engineers' flowsheets without modification for filter operation. Illustrated. F.G.H.

General purpose electromagnet. R. A. Chegwidden. *Bell Lab. Record*, **17** [10] 319–20 (1939).—Construction details of the electromagnet are discussed. Illustrated. P.S.D.

"Huwood" dust collector. Anon. *Colliery Guardian*, **159**, 547 (1939).—This collector resembles a vacuum cleaner. In a cylindrical tank 20 in. in diameter and 3 ft. high is a bag filter inclosing an air injector which pulls dusty air up to the bottom of the bag. On the drill rod is a short collar which has a short slightly conical tube pointing toward the drill hole. The collar also has a connection at right angles for a rubber hose which fastens to the bottom of the tank. The slightly conical tube is inserted in the hole and makes a tight fit, so that all the broken rock and dust is caught in the tank. When a hole is just being started, there is a rubber sheath which fits over the place to be drilled. This folds back as the collar advances, and the conical tube enters the hole. W.D.F.

Improved rotary viscometer. A. H. Nissan, L. V. W. Clark, and A. W. Nash. *Jour. Sci. Instruments*, **17** [2] 33–38 (1940).—A rotary viscometer of the Couette type with an accuracy of 1% in the range of viscosities exceeding 10 poises is described. A sharp-edged weir on the rotating cylinder eliminates end effects. Sources of error and methods of elimination are discussed. 3 figures. J.L.G.

Influence of internal lubrication on drying and fired characteristics of a plastic clay body. H. R. Straight. *Bull. Amer. Ceram. Soc.*, **19** [5] 168–70 (1940).

Laboratory gas furnace for very high temperatures. Vaughan H. Stott. *Trans. Brit. Ceram. Soc.*, **39** [1] 1–6 (1940).—S. describes a furnace for temperatures up to about 1800°C. The tapered brick form a lining about $1^1/_2$ in. thick in the furnace chamber. These brick consist of 80% 220-grit fused alumina bonded with 20% calcined alumina wet-ground for 5 hr. The brick are fired to 1800°C. The furnace chamber is about 12 in. high and 7 in. in diameter and is backed by clay-alumina brick which in turn are backed by insulating brick. The corners between the outside of the furnace chamber and the firebrick are filled with pieces of fused alumina brick and a clay-alumina slip. Tie bars clamp the whole furnace. R.A.H.

Neutral wedge abridged spectrophotometer. Paul A. Clifford and Brooks A. Brice. *Ind. Eng. Chem., Anal. Ed.*, **12** [4] 218–22 (1940).—The apparatus consists of a photometer with a permanent wedge of Jena neutral glass, a tungsten source, and a set of twelve permanent glass filters of relatively high monochromaticity. The glasses composing the filters are listed, and the assembled filters are described by means of spectral transmission curves and values for luminous transmission, spectral centroid, and monochromaticity. Used with a selected filter and an absorption cell of appropriate length, the instrument provides a convenient means of determining the concentration of most colored solutions by reference to simple standard curves. Wedge readings are proportional to density for all filters and hence proportional to concen-

trations for a solute obeying Beer's law. Abridged absorption curves for a solution can be determined by using all the filters and converting scale readings to density values. Various applications are mentioned. Illustrated. F.G.H.

Nichrome furnace of long life. J. G. WINANS AND S. W. CRAM. *Rev. Sci. Instruments*, **10** [9] 272 (1939).—The life of a nichrome furnace was increased by winding the wire over asbestos on a porcelain cylinder with an outside diameter of 6.5 cm. and a length of 36 cm. The cylinder was mounted inside of a second porcelain cylinder with an inside diameter of 10.5 cm. which was surrounded with the asbestos covering. This left an air space between the windings and the outer cylinder of 1.7 cm. The furnace was used for two years at temperatures between 1000° and 1100°C. without burning out. H.E.S.

Psychrometric chart, application and theory: X. WILLIAM GOODMAN. *Heating, Piping & Air Conditioning*, **12** [3] 171–73 (1940).—G. considers the specific volume of air-vapor mixtures and humid air at high pressures. 2 tables. **XI.** *Ibid.*, [4] 239–42.—G. describes some of the geometry of the chart. 3 figures. For Part **IX** see *Ceram. Abs.*, **19** [6] 145 (1940). J.L.G.

Null-type photoelectric spectrophotometer. CHARLES J. BARTON AND JOHN H. YOE. *Ind. Eng. Chem., Anal. Ed.*, **12** [3] 166–68 (1940).—A null-type photoelectric spectrophotometer employing barrier-layer photocells is described. Details of construction and operation are given. Tests of the sensitivity, reproducibility, and accuracy of the instrument are described. The instrument can be used for accurate spectrophotometric measurements, the study of colorimetric methods of analysis, and other types of absorption measurements. Illustrated. F.G.H.

"Quick-immersion" thermocouple for measuring the temperature of liquid steel both before and after being tapped from the furnace. F. H. SCHOFIELD AND A. GRACE. Eighth Report on the Heterogeneity of Steel Ingots. *Iron & Steel Inst. Special Rept.*, No. 25, pp. 239–63 (1939). —The couple is of Pt-Pt Rh wire 0.5 mm. in diameter and is insulated to within 1 cm. of the junction by a two-hole silica sleeve, the whole being enclosed in a silica sheath 8 mm. in diameter and 0.7 to 1 mm. in wall thickness. In most cases this sheath is then covered by a soft steel tube. The couple is mounted on a T made of $1^1/_4$ in. pipe. The leads from the junction are carried to the head of the T where they are attached to asbestos-covered compensating leads. All the metal parts are encased in diatomite insulating brick. By the use of suitable indicating instruments, which are described, the temperature can be read within a few seconds, a period which is too short to do severe damage to either the insulation or the silica sheath. Both may therefore be used for a number of readings. The apparatus has been successfully used in launders, troughs, molds, electric and acid open-hearth furnaces, and ladles. Experiments indicate that it may be possibly be used in the basic open-hearth furnace as well. Details of construction and typical results are included. J.B.A.

Rapid measurement of glass-capillary diameters. G. GLOCKLER AND W. HORWITZ. *Rev. Sci. Instruments*, **10** [9] 271 (1939).—The diameters of glass capillaries employed in the construction of McLeod gauges were determined by (1) weighing a thread of mercury, (2) reading their diameter on a measured microscope, and (3) inserting standard twist drills until the proper size is found. The latter method was the most rapid and was sufficiently accurate for the purpose for which it was employed. H.E.S.

Sedimentation in the laboratory. Design data from laboratory experimentation. HENRY T. WARD AND KARL KAMMERMEYER. *Ind. Eng. Chem.*, **32** [5] 622–26 (1940).—Experimental equipment and technique suitable for the plant laboratory and for instructional purposes in the chemical engineering laboratory have been developed. The equipment permits the determination of settling data without agitation, particle size of the solid, and viscosities of suspensions. A relatively simple correlation is developed between the ratio of ultimate to initial settling height of suspensions of several solids and the weight concentration of the suspensions. A number of viscosity data for suspensions of varying concentrations is presented. An attempt is made to analyze the relative degree of accuracy of the methods of Robinson (*Ceram. Abs.*, **5** [10] 329 (1926)) and Egolf and McCabe (*ibid.*, **18** [3] 81 (1939)) for the reconstruction of settling curves. Modifications of these methods are suggested which improve their utility. Illustrated. F.G.H.

Separation and fractionation of colloidal systems. E. A. HAUSER AND J. E. LYNN. *Ind. Eng. Chem.*, **32** [5] 659–62 (1940).—Knowledge of the particle sizes and particle-size distribution of materials used in various industries is becoming increasingly important. Such knowledge is essential for a better understanding of the fundamental properties and reaction mechanism of these substances. A systematic study of the properties of monodisperse fractions is necessary for the evaluation of polydisperse systems and for any sound approach toward improvements. The various methods now in use for fractionation and determination of particle-size distribution are briefly referred to. The difficulties encountered when dealing with colloidally disperse systems are pointed out. A method is described which permits the determination of particle sizes and particle-size distribution of colloidal dispersions by means of a standard type supercentrifuge of large volumetric capacity. A procedure for obtaining monodisperse fractions of appreciable amount is discussed, and the mathematical evaluation and its theoretical limitations are given. Illustrated. F.G.H.

Simple photoelectric microdensitometer. M. SPIEGEL-ADOLF AND R. H. PECKHAM. *Ind. Eng. Chem., Anal. Ed.*, **12** [3] 182–84 (1940).—A simple photoelectric microdensitometer consisting mainly of a light source, a microscope stand, and a photoelectric cell is described. With this arrangement it is possible to give graphical descriptions of X-ray diffraction patterns. Illustrated. F.G.H.

Spray-gun motion study. B. C. GARDNER. *Steel*, **104** [23] 52–55 (1939).—Attention to a few, simple, underlying rules of motion study and spray-gun technique offers possibilities of greatly increased production with less fatigue and improved quality of work. Illustrated. H.E.S.

Subsieve sizing analysis of finely divided minerals by elutriation or sedimentation: II. KAZUO KANAZAWA. *Suiyokwai-Shi*, **10**, 97–104 (1939); *Chem. Abs.*, **34**, 1897 (1940).—The Wiegner-Gessner sedimentation apparatus does not fractionate but gives only the distribution of the sizes. The distribution of the sizes is calculated from the sedimentation curve which is automatically photographed on bromide paper wound on a rotating drum. This drum can be adjusted to make one revolution in 1 hr. or in 24 hr. as circumstances demand. This apparatus, however, can be applied in sizing analysis of mineral particles from 0.1 mm. downward, but it is not so simple as the Andreasen pipette, and the results cannot be checked under a microscope. It is therefore suitable for testing the settling conditions through its sedimentation curve.

Thermal conductivity type gas analyzer. C. A. HANSEN, JR. *Gen. Elec. Rev.*, **43** [4] 166–69 (1940).—H. describes a thermal conductivity type gas analyzer which continuously indicates gas purity and gives an alarm at any preset value. 4 diagrams, 2 illustrations. L.E.T.

PATENTS

Colorimeter design. E. F. FLINT (Bausch & Lomb Optical Co.). U. S. 120,378, May 7, 1940 (Dec. 2, 1939).

Conveyer for tile, etc. R. M. ISTED. U. S. 2,198,036, April 23, 1940 (June 3, 1938).

Diminishing or preventing foaming. KARL BRODERSEN AND MATHIAS QUAEDVLIEG (I. G. Farbenind. A.-G.). U. S. 2,200,485, May 14, 1940 (March 22, 1939).—The process of preventing foaming of aqueous liquids comprises adding to the liquid a water-insoluble neutral alkyl phosphoric acid ester in sufficient amounts to prevent foaming.

Feeding device for melting pots. W. H. E. KLINGE. Brit. 519,804, April 17, 1940 (Oct. 4, 1938); addition to 517,466 (see "Metal . . .," p. 170).

Manufacture of ceramic articles. A. M. McINTOSH AND A. H. PHILLIPS. Brit. 519,885, April 24, 1940 (Oct. 5, 1938).

Metal-feeding device for melting pots. W. H. E. KLINGE. Brit. 517,466, Feb. 14, 1940 (July 14, 1938).

Method and apparatus for disintegrating molten materials. ALLEN SHERMAN HOPF CO. Brit. 519,671, April 17, 1940 (May 17, 1938).

Method and means for use in packing glassware, chinaware, earthenware, etc. JOHNSEN & JORGENSEN FLINT GLASS, LTD., AND C. N. AUSTIN. Brit. 519,601, April 10, 1940 (Nov. 3, 1938).

Plungers for presses for making perforated articles. GENERAL REFRACTORIES CO. Brit. 519,460, April 10, 1940 (March 10, 1938); divided out of 511,463.

Kilns, Furnaces, Fuels, and Combustion

Antiglare devices on ceramic kilns, ovens, and chimneys: Introduction. ANON. *Trans. Brit. Ceram. Soc.*, **39** [1] 7 (1940). **Air-raid precautions. Wartime lighting order as it affects industrial and commercial premises.** L. WOODHOUSE. *Ibid.*, p. 8. **Night visibility of pottery ovens from the air.** J. RIGBY. *Ibid.*, pp. 9–10. **A.R.P. on factories. Prevention of glare from pottery ovens. Report of Committee of the British Pottery Manufacturers' Federation.** ANON. *Ibid.*, pp. 10–18. **Obscuration of kiln glare in the heavy clay industry.** E. ROWDEN. *Ibid.*, pp. 18–25.—Experiences are cited and suggestions are given for the firemouth and stack treatment of the following types of installations: (*a*) updraft and downdraft pottery ovens, (*b*) updraft and downdraft ovens of the heavy clay industries, (*c*) frit and color kilns, and (*d*) flint and bone calcining kilns. **Discussion.** BENTLEY ET AL. *Ibid.*, pp. 26–35. R.A.H.

Atmospheric oxidation of coal at moderate temperatures. Effect of oxidation on the carbonizing properties of representative coking coals. L. D. SCHMIDT, J. L. ELDER, AND J. D. DAVIS. *Ind. Eng. Chem.*, **32** [4] 548–55 (1940).—Preoxidized samples representative of eight different coal beds were carbonized to measure the effect of oxidation on yields and properties of carbonization products. In general, progressive oxidation results in decreased pore size of coke, followed by poor fusion and complete loss of coking power. The apparent specific gravity of coke increases with oxidation of the coal, but in general this change is accompanied by decreases both in strength of coke and in yield of by-products (except ammonia). The following proved to be sensitive measures of the extent of oxidation: yield of tar; physical properties of coke, especially when made in large retorts (80 kgm. of coal); and agglutinating value. The majority of the coals tested show serious impairment of coking power before they are oxidized enough to decrease the heating value by 1% and before their ultimate and proximate analyses show changes definitely greater than the experimental error of analysis. The amount of oxygen required to cause a decrease of 20% in the hardness of coke shows a three-fold range between the most sensitive and the least sensitive coal tested. This oxygen requirement increases with the volatile matter and decreases with the oxygen content of fresh coals in a manner described by a quantitative relationship. Illustrated. F.G.H.

Coal for firing brick. K. K. *Tonind.-Ztg.*, **63** [35] 405–406 (1939).—All kinds of coal can be used for firing brick if the setting and firing is adapted to the particular type. A proper storage is essential. For coal dust, a mechanical stoker should be used. For the production of porous brick the material best suited must be found by careful experiments. W.K.

Control of firing in kilns. ANON. *Pottery & Glass Record*, **22** [1] 2 (1940).—A new and greatly improved series of cones used in the standardization and control of firing in kilns, ovens, and various kinds of industrial furnaces has recently been placed on the market. These cones have been designated Staffordshire Seger cones "H" series. The original Seger cones were invented by Dr. Hermann Seger of the Royal Porcelain Factory, Charlottenburg. During the World War of 1914–1918, the North Staffordshire Technical College set up a separate department for the manufacture and supply of pyrometric cones which were called Staffordshire Seger cones. When the department was discontinued, Messrs. Harrison & Son, who had been the main distributors of the Staffordshire Seger cone (and previously the agents of the German manufacturers), arranged to take over the manufacture. The new series is claimed to be far superior to anything yet produced; it is a great improvement over the preceding series, in both behavior and reliability. The "H" series cones do not require a revised temperature table as they conform more closely to the existing temperature table than do either the earlier series of British cones or the former German cones. The standardization of the cones is based on a temperature rise of approximately 4°C. per min. For those already using cones, the change-over to the "H" series cones is quite a simple matter. All that is necessary is to fire a set of the "H" series cones beside a set of the cones at present in use. If the kiln or oven is fired correctly, a careful observation of the cones during their melting period (noting the satisfactory sequence of fall of the consecutive numbers), together with an examination of the appearance of the two sets of cones after they are drawn, will indicate at once which cones of the "H" series should be used in substitution in that particular position in the furnace. A successful reading of any temperature within the range 600° to 2000°C. may be obtained with the "H" series cones, as immediately after the tip of a cone touches the base, the next higher cone commences to give a reading. Josiah Wedgwood was a pioneer in the use of cones; between 1782 and 1786 he communicated three papers on pyrometers to the Royal Society, and it is known that he used pyrometric cones. The Sèvres potters were using cones in 1884; Heintz made cones of glass mixtures in 1886, and in the same year Seger built up a series of mixtures from cone No. 1, softening at about 1150°C., to No. 36, softening at about 1700°C. These cones proved so useful that the series was extended by Cramer and others to higher and lower temperatures. A.B.S.

Ignition in beds of solid fuel. M. A. MAYERS AND H. G. LANDAU. *Ind. Eng. Chem.*, **32** [4] 563–68 (1940).—A nomograph has been designed for the calculation of the rate at which fuel can be ignited in pure underfeed burning when the characteristics of the fuel bed are known. By its use, better values than have heretofore been available for the relation between the air flow rate and the rate of combustion reaction and between air flow rate and the rate of heat transfer between the gases and solids of the fuel bed have been calculated from the data on underfeed burning published by the United States Bureau of Mines (*Ceram. Abs.*, **13** [11] 301 (1934)). The significance of ignition temperature in such fuel beds is discussed, and its dependence on the characteristics of the bed is shown. A method is developed for calculating the effective ignition temperatures under specified conditions when the reactivity characteristic is known. By the use of this method in conjunction with the nomograph, the rate of ignition of a given fuel under specified conditions can be calculated. Illustrated. F.G.H.

Interpretation and use of the individual laboratory coal test. G. B. GOULD. *Combustion*, **11** [5] 31–37 (1939); see *Ceram. Abs.*, **17** [4] 154 (1938). H.E.S.

New burner system features wider temperature range and closer control. H. M. HEYN. *Ind. Heating*, **7** [4] 312–14 (1940).—As convection heating requires the circulation of large volumes of hot gases, usually at temperatures up to 1350°F., the ordinary type of burner in the furnace is turned down to give this temperature; this reduces the volume of hot gases. To overcome this difficulty, a new system (Conjecto firing) has been developed in which an additional volume of air is introduced at a low temperature

and automatically mixed with the hot products of combustion by an arrangement of twin nozzles in a burner; one nozzle burns the fuel completely, and air is injected through the other in the desired quantity to produce the large volume of hot gases required for convection heating. An example is described. M.H.

Optical temperature measurement of luminous hydrocarbon flames. G. NAESER. *Jour. Inst. Fuel*, **12** [64] S38–41 (1939).—N. describes the principles of color pyrometry and points out that, since the color pyrometer is known to give a value for a flame temperature which errs on the high side while the brightness or intensity type of pyrometer gives too low a value, an instrument which measures both at the same time is of considerable advantage. Such an instrument is described; it is independent of variations in color sensitivity of the observer's eye. Measurements of flame temperatures with the instrument are given. The method is confined to flames which have a continuous spectrum. H.E.S.

Space requirement for the combustion of pulverized coal. H. C. HOTTEL AND I. MCC. STEWART. *Ind. Eng. Chem.*, **32** [5] 719–30 (1940).—The problem of space requirement for the combustion of pulverized coal is attacked by combining a suitable particle size distribution law applicable to samples of pulverized coal, the laws of burning of individual particles, and reasonable assumptions concerning the mechanism of burning particles in a cloud. The resulting relationship, expressed graphically in dimensionless terms, predicts the percentage of the original fixed carbon in the coal which passes out unburned as a function of chamber size, firing rate, fineness of grinding, excess air, approximate flame temperature, and a so-called combustion constant to be determined experimentally. The theoretical relation so developed is applied to experimental data on the effects of fineness of grinding and of temperature on the unburned-carbon losses from four types of coal. Combustion constants are determined which bring the data onto a single narrow band and permit the conclusion that the performance of other pulverized fuel-fired combustion chambers may be similarly analyzed. Illustrated. F.G.H.

Temperature of flame gases. W. T. DAVID. *Engineering*, **149** [3869] 240 (1940).—The high results, often 100° or more, obtained by the sodium-line reversal method may be due to either the nonhomogeneity of the gases prior to combustion or the communication of excess energy from the CO_2 and H_2O molecules to the sodium atoms. B.C.R.

Use of laboratory tests in judging coal values. G. B. GOULD. *Combustion*, **11** [4] 29–34 (1939).—G. gives information as to what both buyer and seller should expect with regard to variations in a series of shipments and discusses the relation of coal specifications to the normal pattern. See "Judging . . . ," *Ceram. Abs.*, **19** [2] 51 (1940). H.E.S.

SEPARATE PUBLICATION

Treatment of Coal with Oil. J. M. PILCHER AND R. A. SHERMAN. *Bituminous Coal Research, Inc., Tech. Rept.*, No. VI, 36 pp. (1939); reviewed in *Combustion*, **11** [3] 47 (1939).—Petroleum oils and blends of oil with wax and asphalt are suitable materials for allaying dust, but to obtain proper treatment at minimum expense, the correct oil must be used for different coals. Low volatile coals from West Virginia may be treated equally well with light or heavy oils; high-volatile coals from West Virginia, Pennsylvania, and Kentucky require higher viscosity oils; coals from Indiana, Illinois, and the far west are best treated with heavy highly viscous oils or blends of oil and wax or oil and asphalt. This treatment eliminates 80 to 95% of the coarse dust and 95 to 99% of the floating dust, although it has no appreciable effect on the burning of coal or on the spontaneous heating of stored coal. See "Use . . . ," *Ceram. Abs.*, **19** [2] 52 (1940). H.E.S.

PATENTS

Furnace-heating element and supports therefor. G. H. S. GRENE AND WILD-BARFIELD ELECTRIC FURNACES, LTD. Brit. 520,200, May 1, 1940 (Oct. 14, 1938).

Gas burner. E. L. DENNIS (Coppus Engineering Corp.). Can. 387,846, April 9, 1940 (Aug. 15, 1938). P. J. SONNER. Can. 387,735, April 2, 1940 (May 10, 1937). G.M.H.

Tire mounting for rotary driers, kilns, etc. W. H. HOW (Struthers Wells-Titusville Corp.). U. S. 2,198,820, April 30, 1940 (March 30, 1939).

Geology

Action of hydrochloric acid on colloidal silicic acid. V. N. KRESTINSKAYA AND N. E. NATANSON. *Acta Physicochim. U.R.S.S.*, **7**, 915 (1937); *Trans. Brit. Ceram. Soc.*, **39** [1] 8A (1940).—The action of HCl as (1) coagulating agent, (2) stabilizing agent, and (3) peptizing agent was studied on silica sols. Only concentrated HCl produces coagulation. Experiments on transference and cataphoresis show that HCl may abolish but does not reverse the charge. Dialysis experiments indicate, further, that HCl does not promote the disintegration of the micelles. The stabilizing action of HCl is attributed to the strengthening of the hydrophilic properties of the sols, which can be due to (*a*) appearance of freshly formed H_2SiO_3, (*b*) transition of the H_2SiO_3 to a different form of higher solubility, and (*c*) removal of charge from the micelles. Addition of small amounts of NaOH increases the η of SiO_2 sols, while small additions of HCl reduce it. This is attributed to the effect of electroviscosity which increases with the dissociation of H_2SiO_3 and decreases when the latter is reduced.

Alunite of Puy-de-Dôme. V. CHARRIN. *Argile*, No. 198, pp. 1–5 (1940).—Alunite, K_2O, SO_3, Al_2O_3, SO, $2Al_2O_3$, $6H_2O$, which was the source of alum for centuries, has been replaced by natural potassium salts (kainite, sylvinite, and schonite). An industrial use is again being sought for alunite, not for producing alum, but for producing its separate constituents, potash and alumina. The experiments are based on the differences in resistance to calcination of the two sulfates: at 600° to 800°, the aluminum sulfate dissociates into sulfuric acid and aluminum, but the potassium sulfate remains intact. After the potassium sulfate is washed and removed, the residue is comparable to a bauxite of medium quality. Any predictions as to the outcome of the experiments are premature. Alunite is most commonly found in irregular veins of massive trachytic rock with kaolins and clays, and may be white, reddish, or gray according to its purity. Its density is 2.65 and its hardness is 3.5 and 4; the theoretical composition is 35.49 sulfuric acid, 10.02 potash, 39.65 alumina, and 14.83% water. Two alunite deposits in France in the Puy-de-Dôme region and their exploitation are described. M.V.C.

Bauxite of Poços de Caldas. M. DA SILVA PINTO. *Boll. do S.F.P.M.* [Rio de Janeiro], No. 22 (1938); *Neues Jahrb. Mineral., Geol.*, Ref. II, **1938**, 647; *Chem. Abs.*, **34**, 1945 (1940).—The high plateau of Poços de Caldas (Minas Geraes, 250 m. W.N.W. of Rio) consists essentially of foyaite and phonolite, the surface of which, through extensive post-Tertiary weathering, has been lateritized with the production of a layer of bauxite 3 to 5 m. thick beneath about 30 cm. of a sterile layer. There is no "iron hat," and the transition to the underlying parent rock is very sharp. The average composition of the laterite is Al_2O_3 60, Fe_2O_3 5 to 7, TiO_2 2, SiO_2 1, and H_2O 30%. The Fe content is almost identical with that of the parent phonolite. The total amount of bauxite is estimated at 16×10^7 tons.

Beryl, a case history. L. G. BLISS. *Bull. Amer. Ceram. Soc.*, **19** [5] 159–60 (1940).

Coagulation curves of some fire clays. V. L. BOSAZZA. *Trans. Brit. Ceram. Soc.*, **39** [2] 37–40 (1940).—From observations made on a clay in which flocculation was extremely slow, in a well lighted room, in a dark room, and

when a strong light was directly focussed on the tube of suspended clay particles, B. concludes that the "rhythmic" coagulation of the clay is in all probability due to convection currents. R.A.H.

Dispersion of clays and shales by fluid motion. ALLEN D. GARRISON, K. C. TEN BRINK, AND P. B. ELKIN. *Amer. Inst. Mining Met. Engrs. Tech. Pub.*, No. 1125; *Petroleum Tech.*, **2** [4] 11 pp. (1939).—The viscosity of a clay suspension usually decreases when flowing more rapidly and vice versa, and there is a time lag until equilibrium is reached. The clays studied showed a viscosity which fell to a minimum and then rose. Factors which increase this rate of rise of viscosity are (1) aging, (2) increase in concentration, and (3) increase of pH. These results may be interpreted satisfactorily if it is assumed that the rise in viscosity is due to increased colloidal dispersion of the clays and to subsequent increased hydration of the particles. Particle-size measurements by sedimentation show fewer large and more small particles in the stirred clay. W.D.F.

Effect of temperature on the moisture-content surface-force curve of soil. H. A. WADSWORTH. *Soil Sci.*, **47** [6] 473–78 (1939).—Lowering the temperature at which the determination is made, within certain limits, increases the moisture content of a soil in equilibrium with a specified relative humidity. With one soil studied there is some evidence that the curves cross at a relatively high humidity. G.R.S.

Experimental flotation of Washington magnesite ores. J. B. CLEMMER, H. A. DOERNER, AND F. D. DEVANEY. *Amer. Inst. Mining Met. Engrs. Tech. Pub.*, No. 1148; *Mining Tech.*, **4** [1] 10 pp. (1940).—The magnesite at Clewelah, Wash., is interfingered with dolomite, and calcite, talc, serpentine, quartz, and shale are disseminated through it. Chemical analysis is necessary to determine good ore. The sorted magnesite is not of the best grade, and the rejects contain a lot of magnesia. The tests were made in order to obtain high-grade magnesia with less than 1% SiO_2 and 2% CaO. The selected ore and the rejected material were both tried. The selected ore was used in batch flotation tests and then in pilot plant tests. There were six flotation cells. The cationic collectors DLT 699 and Emulsol 903-L gave the desired purity in the product when added at the rate of 1 lb. of collector per ton of ore. They gave 95% recovery of the magnesia. In the case of low-grade mine rejects, the siliceous minerals and calcite were floated by cationic reagents; the magnesite was then floated from the dolomite by soap. A broad range of purity in magnesite products, well within the specifications for refractory magnesia, can be obtained. W.D.F.

Feldspars from crystalline spessartites. RUDOLF MOSEBACH. *Senckbergiana*, **20**, 346–63 (1938); *Neues Jahrb. Mineral., Geol.*, Ref. I, **1939**, p. 566; *Chem. Abs.*, **34**, 2290 (1940).—Analyses and optical properties of six potash feldspars from various pegmatites, kersantite and augen-gneiss, and of one plagioclase from pegmatite are compared, and their probable relations and origins are discussed.

Flint clays and flint-clay refractories of Southern California. B. M. BURCHFIEL AND HENRY MULRYAN. *Bull. Amer. Ceram. Soc.*, **19** [5] 161–63 (1940).

Flotation process draws interest of cement industry. ANON. *Concrete, Cement Mill Ed.*, **48**, 102–103 (1940).—A recently constructed plant at Parana, Argentina, 200 miles north of Buenos Aires, was designed to use froth flotation from the start. There is a clay overburden, 68% silica. A soft tosca, 66% silica and 5% calcium carbonate, overlies consolidated marl, 20% silica and 72% calcium carbonate; next lower is a crystalline limestone, 10% silica and 90% calcium carbonate. The flotation must recover clay and carbonate and discard much of the silica. In the plant the cell feed goes through a turbomixer, four rougher flotation cells in series, four scavenger cells in series, and two cleaner cells in series. The reagent used is Cyanamid 608, and it is fed into each cell. W.D.F.

Froth flotation concentration. C. C. DEWITT. *Ind. Eng. Chem.*, **32** [5] 652–58 (1940).—The discoveries leading to the successful operation of the froth flotation process for the recovery of minerals are briefly reviewed. Several theories of mineral flotation as related to surface chemistry are discussed, and the opinions of various investigators are given. The important physicochemical characteristics of flotation reagents are reported, including those used for the recovery of metallic sulfides, oxides, and carbonates. The current practice in metallic mineral recovery for some of the more important minerals is reviewed, and the concentration of nonmetallic minerals by froth flotation as well as their agglomeration concentration is discussed. Some of the important research problems related to mineral flotation which remain unsolved are summarized. Illustrated. F.G.H.

Geologic features of some deposits of bleaching clay. G. AUSTIN SCHROTER AND IAN CAMPBELL. *Amer. Inst. Mining Met. Engrs. Tech. Pub.*, No. 1139; *Mining Tech.*, **4** [1] 31 pp. (1940).—The clays are either (*a*) naturally adsorptive or (*b*) activable. Montmorillonite is the most common clay mineral in both. The texture of *a* is granular or massive, with usually a light color; *b* usually has a waxy luster and is commonly bentonite. Structures shown include preformational and postformational features. The most common preformational structure is the occurrence of clays formed from subaqueous tuffs. Postformational structures are due to plastic flow of clay and a thickened outcrop due to dehydration and swelling. An outcrop criterion is seen in the clay bloom in arid or semiarid regions. This is a crackly checkerboard appearance due to swelling. The origin of the clay is separate from the origin of the bleaching power. Any rock of favorable composition can alter to a bleaching clay. Acidic solutions are needed to develop the bleaching efficiency. Authigenic hydrothermal deposits are rare, but near Bristol, Nevada, a diabase has been so altered. Authigenic deposits due to cold meteoric solutions are the most common. There is little or no positive evidence to indicate allogenic deposition. A transported clay may be activated after it is deposited; it then becomes an authigenic deposit. Wind is not likely to transport the bleaching clays after they are formed. W.D.F.

Identification of minerals in soil colloids. G. NAGELSCHMIDT. *Jour. Agr. Sci.*, **29**, 477–501 (1939).—X-ray, optical, dehydration, and chemical methods in use for the identification of minerals in soil colloids are discussed with special regard to their limitations. These are mainly due to the uncertainties about the variation of physical properties of standard minerals with decreasing grain size and the possible existence and importance of amorphous material. The aggregate method in X-ray analysis, expecially important for soil colloids, is described. N. discusses various techniques for dehydration and optical analysis and concludes that they are useful only when used in combination with X-ray data. The advantages of combining various chemical methods with X-ray analysis are pointed out. Standard data are given for a number of soil minerals, and the evidence for their occurrence in soil colloids is reviewed. These minerals are quartz, cristobalite, oxides and hydroxides of iron and aluminum, and minerals of the kaolinite, montmorillonite, and mica groups. Illustrated. P.S.D.

Methodology of grain size and mineral analyses of pelites (on the basis of research on elutriation analysis and roentgenographical and microscopical studies of different deposits): Special part. HANS J. HARKORT. *Sprechsaal*, **72** [44] 530–31; [45] 539–41; [46] 545–48; [47] 554–55; [48] 561–64; [49] 571–73; [50] 579–83; [51] 589–91 (1939).—By means of elutriation analyses and roentgenographic and microscopic examination of three bolus clays, a micaceous sand, and a Hupper earth (kaolin sand), the separation into particle-size fractions and the determination of the mineral constituents (completed in the case of the bolus clay by chemical analysis) were made. To determine the mineral constituents, colloid fractions ($<1\ \mu$) were determined. The results and problems to which the research led were treated in relation to their methodological significance. The possibilities and limitations of the different methods are shown as they appear in the different tests. Particle size analyses can have two different objectives: the determination of the true particle size, i.e.,

the primary particles, and the determination of the apparent particle size. The two objectives must correspond to the kind of separation to be obtained, that is, maximal dispersion (separation into primary particles) and natural dispersion. Both of these types of dispersion are characterized, and their possibilities are discussed. For studying the mineral composition, only maximal dispersion can be considered for the preparation. H. gives a survey from literature of the efficacy of the different methods of preparation in regard to the most complete division into primary particles (maximal dispersion). The sedimentation process was satisfactory for the separation into particle-size fractions (Atterberg cylinder: sedimentation jars and cylinders and the removal of the suspensions above by vacuum suction through a glass tube). In the method of preparation by heating with distilled water and grinding, the sedimentation of the bolus clays is not possible without the addition of ammonia because of the resulting coagulation. Repeating the ammonia addition before each sedimentation increases the fraction $<2\ \mu$ more than a single addition. Coagulation will be raised little in spite of the washing out of the electrolyte. In the bolus clays, the process of preparation by agitating and grinding (without heating) and sedimentation in Li_2CO_3 or $Na_4P_2O_7$ increases the fraction $<2\ \mu$ 37, 70, and 79% and lowers the coarse constituents. The action of these electrolytic additions is augmented, however, by repeated grinding before every sedimentation; the repeatedly divided aggregates are either not "caught" by the preparation or they form again during sedimentation because of too small an amount of colloidal particles and the effect of sedimentation on coagulation. When the sedimentation analysis is used, control of the separation of particles $<2\ \mu$ is necessary before each sedimentation. This control can be made neither with pipette analysis nor by study of the effect of the sedimentation on the coagulation. The pipette analysis, even with the use of additions of electrolytes, does not fill the requirements for determining the division of particles. Comparison of the results of the Kopeck analysis with those of the sedimentation analyses shows that, with a higher content of particles $<10\ \mu$, the fraction 50 to 10μ or 15μ is increased by the coagulation taking place in the large elutriating cylinder. The characterization of minerals is necessary for their identification in the mix, and it may be done roentgenographically or microscopically. In both cases, the extent of the variation must be noted. With the possibility of variation of the Roentgen diagram, only diagram types or mineral types can be spoken of. The three groups of clay minerals (kaolin, muscovite-sericite, and montmorillonite-nontronite), as well as göthite or pea ore, were characterized roentgenographically and microscopically as far as possible on the basis of the available data (up to 1935). The determination of the minerals in the mixture is complicated by the presence of other ingredients, and the chances for detection are lessened. The fractions $<2\ \mu$ can only be determined microscopically in the form of aggregates; the possibility of recognizing impurities in the mixtures is therefore very slight. In aggregates, a mean refraction of light of both components appears. Detection by the roentgenograph is conditioned by the power of interference and the kind of covering layer of the diagram. Knowledge of the characteristic interferences, i.e., those intensive lines which are not covered over with the weak lines of another diagram, is especially important. In the interpretation of diagrams of covering layers, the variations in the intensity and width of the lines must be noted. Besides the line sequence and the power of interference of the components, their degree of dispersion and concentration in the mixture also play a part. As an example of this, three clay mineral groups, mixtures of iron oxide minerals with kaolin, and mixtures with nonclayey minerals, especially quartz, were treated; the diagrams of the covering layers are discussed on the basis of the interference of the components arranged according to the intensity. After a short survey of the geological origin of the test materials, the comparative sedimentation analyses and their results are described with regard to the division obtained. The results of the experiments are given in tabulated form. This work was concluded in February, 1937; the results of later experiments in the field of clay minerals, therefore, are not included. A list of references on mineral and grain size analysis, methods of preparation, and research material is given. See *Ceram. Abs.*, **18** [11] 311 (1939).
M.V.C.

Mineral assemblage of the "White Silt" Terraces in the Okanagan Valley, British Columbia. CHARLES MEYER AND KEITH YENNE. *Jour. Sed. Petrology*, **10** [1] 8–11 (1940).—Mechanical screen and pipette analyses and a study of the heavy minerals support the belief that these sediments are accumulations of rock flour at or near the mouths of streams emptying into ice-dammed lakes which occupied the valley at the close of the Pleistocene.
G.M.H.

Minerals present in soil colloids: I, Descriptions and methods for identification. STERLING B. HENDRICKS AND LYLE T. ALEXANDER. *Soil Sci.*, **48** [3] 257–71 (1939).—The nature and composition of minerals present in the colloidal fractions of soils are discussed, and methods for identifying these minerals are described. The most common components of soil colloids are kaolin minerals (kaolinite or halloysite), hydrous mica, montmorillonites, quartz, göthite, and hematite. These can be identified and their amounts estimated by simultaneous use of suitable chemical analyses, X-ray observations, and observations of behavior upon heating. X-ray measurements, though desirable, are not indispensable, and methods, though somewhat inadequate, for identification of clay minerals can readily be utilized in most soil laboratories. The camera for making X-ray diffraction photographs of oriented samples and the apparatus used for differential thermal analysis are illustrated. **II, Estimation in some representative soils.** L. T. ALEXANDER, S. B. HENDRICKS, AND R. A. NELSON. *Ibid.*, [8] 273–79.—Minerals present in the colloidal fraction of 15 soils from central United States were identified, and their amounts were determined by the use of chemical, thermal, and X-ray diffraction methods. Kaolinite and free oxides and hydrous oxides of iron were the predominant components of the red podsolic soils examined. Gray-brown podsolic soil colloids contained these minerals associated with appreciable amounts of hydrous mica. Single samples of colloids separated from soils of the chernozem, prairie, and desert groups were studied.
G.R.S.

Mines and minerals of New Hampshire. HAROLD M. BANNERMAN. *Rept. New England Assn. Chem. Teachers*, **41**, 4–14 (1939); *Chem. Abs.*, **34**, 1594 (1940).—B. gives a survey of early mining activities, the occurrence of Cu, Pb, Zn, Ag, Au, feldspar, mica, etc., and the New Hampshire mineral industry.

Pegmatites of the Spruce Pine district, North Carolina: II. C. S. MAURICE. *Econ. Geol.*, **35** [2] 158–87 (1940).—M. considers miscellaneous pegmatites, aplites, and other rocks and gives a summary of conclusions on the district. A genesis of plagioclase and commercial sheet muscovite in pegmatites is included. Illustrated. 47 references. For Part I see *Ceram. Abs.*, **19** [5] 127 (1940). J.L.G.

Permeability of saturated sands, soils, and clays. P. C. CARMAN. *Jour. Agr. Sci.*, **29**, 262–73 (1939).—The permeability of a water-saturated sand or fine powder can be calculated with considerable accuracy if the porosity and specific surface are known. The Kozeny theory leads to a very useful relationship between permeability and porosity. Clays do not conform to the theory in its simple form, but it may be modified to give a satisfactory representation of the data available. Physical grounds for this modified theory are discussed. From the modified theory it is deduced that clays may have zero permeability at a considerable porosity.
P.S.D.

Plant growth and the breakdown of inorganic soil colloids. W. A. ALBRIGHT, E. R. GRAHAM, AND C. E. FERGUSON. *Soil Sci.*, **47** [6] 455–57 (1939).—A clay, electrodialyzed free of its cations and then saturated with only Ba, Mg, and Ca to a pH of 6.9 or 7.0, was broken down by plant growth with the release of the silicon, aluminum, and iron to the extent of 2 or 3% of the total clay. G.R.S.

Rates of temperature changes in soils at various moisture contents. H. A. WADSWORTH. *Soil Sci.*, **47** [6] 467–71 (1939).—Evidence is offered to support the assumption that the simple cooling of a soil generates heat. When cold soils are warmed, heat is absorbed without a corresponding temperature increase. The problem was attacked through a study of the rates of temperature change and a comparison with the classic law of cooling. G.R.S.

Study of phases of chemical control in clay suspensions. ALLEN D. GARRISON AND K. C. TEN BRINK. *Amer. Inst. Mining Met. Engrs. Tech. Pub.*, No. 1124; *Petroleum Tech.*, **2** [4] 20 pp. (1939).—As none of the existing instruments was satisfactory for measuring the flow characteristics of plastic fluids, a new instrument was developed. It can be run for a long time, the rate of flow can be controlled over a wide range, and the cup has no baffles to obstruct smooth flow. It was calibrated with known liquids. Centipoises plotted against 1/r.p.m. gave straight lines, the viscosity increasing as speed decreased, for three kaolin suspensions, SiO_2, $BaSO_4$, and S. In bentonite, the viscosity decreased from the straight line at high speed. This was due mainly to the very fine fraction. Factors in viscosity are (1) that of the medium, (2) that due to separate solid particles, (3) that due to forces attracting particles, and (4) hydration. At 100 r.p.m., tannin and sodium hexametaphosphate decreased kaolin viscosity from 165 to 10 centipoises and bentonite from 170 to 100 and increased the curvature in the bentonite curve. Flocculating agents lower 3 but not 4. At 100 r.p.m., bentonite viscosity varied with pH as follows: 2.0, 160; 2.7, 10; 4.5, 45; 10.5, 22; and 11.3, 180. These values are for NaOH; $Ba(OH)_2$ gives similar values. Tests with different sodium salt deflocculating agents show that their relative effectiveness is not in the same order as the solubility of their alkaline earth salts and that their removal is not the complete explanation. Treatment with $Ba(OH)_2$ formed a barium clay. As the barium ion is less hydrated the clay is less hydrated and is more easily flocculated. Deflocculation agents used in the past influenced structural viscosity only. The control of hydration is not so simple. W.D.F.

BOOKS AND SEPARATE PUBLICATION

Magnesite Industry in Salem. G. KRISHNAMACHARIAR. Govt. Central Press, Hyderabad. 30 pp.—Of all the magnesite deposits found in India the most important are those of the Chalk hills near Salem. The reserves in these hills are practically unlimited. The richest portions stand up in hillocks rising 140 ft. above the level of the plains. Of the two areas comprising the Chalk hills, the larger one, known as the Chetty Chavadi Jaghir, about $3^1/_2$ sq. miles in extent, contains between 5 and 15 million tons of raw material, pure white in color, yielding 47.42% $MgCO_3$, while the calcined product gives about 96 to 98% $MgCO_3$. The uses of magnesite are detailed. The manufacture of solid carbon dioxide or dry ice and liquid carbon dioxide will form an important item in the proposed Salem magnesite industry next only to the manufacture of magnesia or Sorel cement, magnesium metal, and refractory brick. Three appendixes are included. A.P.S.

Nonmetallic Mineral Industries in 1939. PAUL M. TYLER AND OLIVER BOWLES. *U. S. Bur. Mines Information Circ.*, No. 7106, 27 pp. Free.—The history and technologic advance during 1939 are summarized for the following nonmetallic commodities: aggregates, asbestos, barite, bauxite, bentonite, borax, carbon dioxide, cement, clay (bleaching), clay (china), diamonds, dolomite, feldspar, graphite, grinding pebbles, gypsum, Iceland spar, kyanite, andalusite, dumortierite, lime, lithium minerals, magnesite, magnesium sulfate and other magnesium compounds, mica, mineral wool, nepheline syenite, phosphate rock, potash, pyrophyllite, salt, slate, sodium sulfate, stone (crushed), stone (dimension), and vermiculite. R.A.H.

Soil Analysis. Handbook of Physical and Chemical Methods. 2d ed. C. H. WRIGHT. T. Murby and Co., London, 1939. 276 pp. Reviewed in *Chem. & Ind.*, **58** [33] 786 (1939).—The book has been revised and brought up to date, particularly with regard to freezing point, hydrogen-ion concentration, inorganic soil colloids, and mechanical analysis. Part I deals with physical methods, the sections on hydrogen-ion concentration and mechanical analysis being particularly fully detailed. Part II covers general chemical methods. Part III, which includes all the special chemical methods, occupies nearly half the book. The subjects of carbon, carbon dioxide, clay fractions, water extracts, and base exchange are well treated. G.R.S.

PATENTS

Concentrating nonmetallic minerals. C. H. PEDDRICK, JR., AND J. H. WEIS (Feldspathic Research Corp.). U. S. 2,198,972, April 30, 1940 (April 1, 1938).

Purification of sand. L. P. CURTIN (H. C. Parker). U. S. 2,198,527, April 23, 1940 (Sept. 10, 1938).—In the purification of crude sands containing iron as an impurity, the process comprises leaching such a crude sand with a leach liquor containing oxalic acid, removing the spent liquor from the purified sand, digesting the spent liquor with calcium sulfate to precipitate the oxalate values as calcium oxalate, separating the solids from the liquor, treating the solids with sulfuric acid to convert the oxalate content into oxalic acid, and returning the oxalic acid to the first step of the process.

Recovery of uranium and vanadium from carnotite ores. HERMAN FLECK. U. S. 2,199,696, May 7, 1940 (Dec. 17, 1937).

Solubilizing igneous rocks. G. A. BLANC AND F. JOURDAN. Brit. 519,924, April 24, 1940 (July 1, 1937).

Chemistry and Physics

Assignment of uncertainties to the data of chemistry and physics with specific recommendations for thermochemistry. FREDERICK D. ROSSINI AND W. EDWARDS DEMING. *Jour. Wash. Acad. Sci.*, **29** [10] 416–40 (1939).—The theory of probability and error is discussed from the case of a single sample or set of observations or a pair of samples or sets of observations. Functional concordance is also discussed. The propagation and combination of errors is treated briefly. The application to measurements is generally treated, and a number of definite recommendations for thermochemistry is given. The advantage of assigning an uncertainty interval to each value is stressed. This interval is twice the "over-all" standard deviation. J.B.A.

Colorimetric microdetermination of magnesium. C. P. SIDERIS. *Ind. Eng. Chem., Anal. Ed.*, **12** [4] 232–33 (1940).—Magnesium is precipitated as magnesium hydroxyquinolinate. The precipitate is dissolved in hydrochloric acid and made to volume, and an aliquot is buffered with sodium acetate and then treated with ferric chloride. The green-black pigment, formed by the reaction of Fe^{+++} with hydroxyquinoline, is extracted with chloroform, made to volume with butyl alcohol, and compared against a standard in the colorimeter. Illustrated. F.G.H.

Cone deformation study in a part of the system calcium oxide–iron oxide. KENNETH REES AND H. G. FISK. *Jour. Amer. Ceram. Soc.*, **23** [6] 185–86 (1940).

Crystallochemical investigation of the field of the spinel luminophore. ERICH TIEDE AND ERNST VILLAIN. *Ber. Deut. Chem. Ges.*, **73** [3] 274–79 (1940).—Experiments have shown that manganese gives a strong red fluorescence with ultraviolet radiation, whereby the spinel lattice is a necessary condition. Pure Mg_2TiO_4 is not excited in ultraviolet light. Highly purified precipitated TiO_2 and pure MgO were heated to 1200°C. for 30 min., resulting in a pure white magnesium titanate. Samples were treated with drops of heavy metal solutions (Fe, Mn, Cu, Cr, Ag, Ni, Co, Rh, W, U, etc.) and then heated to

1200°C. for 20 min. Only the titanate activated with Mn showed luminescence with ultraviolet light. Manganese was added as a sulfate or acetate, and 0.5 mgm. per 1 gm. titanate gave maximum effects (red fluorescence). The color of the white magnesium titanate is changed with Mn additions from yellowish to light brown. When the Mn-containing titanate was heated in nitrogen its luminescence was destroyed; heating in oxygen gave the best results. 7 illustrations. L.E.T.

Crystallographic modification of aluminum oxide. A. S. IVANOV. *Trudy Tsentral. Nauch.-Issledovatel. Lab. Kamnei Samotsvetov Tr. "Russkie Samotsvety,"* **1938**, No. 4, pp. 44–58; *Khim. Referat. Zhur.*, **2** [5] 31 (1939); *Chem. Abs.*, **34**, 2228 (1940).—I. reviews the literature useful for the synthesis of corundum. Data are given for all known modifications of Al_2O_3 with references for each modification separately.

Determination of aluminum by photometric fluorescence measurement. CHARLES E. WHITE AND C. S. LOWE. *Ind. Eng. Chem., Anal. Ed.*, **12** [4] 229–31 (1940).—Aluminum may be determined quantitatively by photometric measurement of the intensity of fluorescent solutions produced by the aluminum-morin reaction. Intensity measurements may be made with the Pulfrich or a photoelectric photometer. The amount of morin and alcohol as well as the temperature and pH must be controlled. Illustrated. F.G.H.

Determination of magnesium in water. W. G. MOFFITT. *Jour. Soc. Chem. Ind.* [London], **58** [3] 125–26 (1939).—In the titration of magnesium with potassium palmitate, the end point is difficult to detect, particularly in the presence of oxalate. By removing calcium as calcium carbonate, the use of oxalate was avoided. Titration curves were investigated to determine the conditions required for obtaining a sharp end point. Satisfactory results were obtained by titrating in the presence of a trace of acid, using a mixture of indicators having a sharp color change at pH 8.2. G.R.S.

Determination of silica and R_2O_3 in Portland cement. LYLE R. DAWSON AND RALPH V. ANDES. *Ind. Eng. Chem., Anal. Ed.*, **12** [3] 138–39 (1940).—It appears that, in the analysis of Portland cement and cement clinker, the silica remaining with the ignited R_2O_3 may, under carefully controlled conditions, be determined by direct hydrofluorization. A rapid method, in which the silica and $R_2O_3 \cdot xH_2O$ precipitates are combined, has been tested. Fairly accurate values may be obtained, although there is some evidence that the value for silica may tend to be slightly high. This may be due to the loss, as fluorides, of a small amount of titanium or other elements ordinarily counted in the R_2O_3. The use of bromothymol blue in precipitating the hydrous oxides of iron and aluminum has been tested, and it gives excellent results. F.G.H.

Determination of tungsten by a volumetric method. M. L. HOLT AND ALLEN G. GRAY. *Ind. Eng. Chem., Anal. Ed.*, **12** [3] 144–46 (1940).—This proposed volumetric method for the determination of tungsten is based on the reduction of W^{VI} to W^{III} by liquid lead amalgam in a specially designed reductor. The reduced tungsten is reoxidized with ferric iron, and the resulting ferrous iron is titrated with a standard dichromate solution, using diphenylamine sulfonic acid as an indicator. Illustrated. F.G.H.

Determining emulsifying efficiencies. LEONARD H. COHAN AND NORMAN HACKERMAN. *Ind. Eng. Chem., Anal. Ed.*, **12** [4] 210–13 (1940).—The apparatus and procedure for a new method, based on turbidity measurement, of determining emulsifying efficiency are described, together with a convenient standard emulsion. The new method is compared with microscopic examination and with the measurement of the time of creaming of the emulsions. Results on a colloid mill, a homogenizer, and a new type of emulsifier are presented. A bibliography on methods of particle size analysis applicable to the study of emulsions and suspensions is included. Illustrated. F.G.H.

Dielectric properties of insulating materials: III, Alternating and direct current conductivity. E. J. MURPHY AND S. O. MORGAN. *Bell System Tech. Jour.*, **18** [3] 502–37 (1939).—The authors deal with the variation of a.-c. conductivity with frequency and the variation of apparent d.-c. conductivity with charging time for dielectrics exhibiting anomalous dispersion, i.e., having dielectric constants which decrease with increasing frequency. The a.-c. conductivity of a dielectric exhibiting simple anomalous dispersion approaches a constant limiting value, γ_∞, as the frequency increases. γ_∞ possesses properties similar to those of the conductivity due to free ions, although in most cases it depends upon the motions of polar molecules or bound ions. The apparent conductivity for the constant (d.-c.) potential approaches an initial value as the charging time is diminished. This initial conductivity, γ_0, is equal to the limiting value of the a.-c. conductivity attained at high frequencies (γ_∞), a relationship which simplifies the description of the behavior of dielectrics exhibiting simple anomalous dispersion. Dielectrics possessing the property of anomalous dispersion then have two conductivities: one is due to the local motions of polar molecules or bound ions and the other is due to the migration of free ions to the electrodes. Both γ_0 and γ_∞ refer to methods of measurement. In many nonhomogeneous dielectrics, especially in those in which one part has a much higher resistivity than the remainder, both γ_0 and γ_∞ may be a measure of a free-ion conductivity. As the equality of γ_0 and γ_∞ is independent of the nature of the polarization responsible for them, experimental agreement between a.-c. and d.-c. measurements cannot be used to distinguish whether the dielectric loss in a material is due to polar molecules, to bound ions, or to free ions present in a nonhomogeneous dielectric. In homogeneous dielectrics, however, γ_0 (or γ_∞) is a conductivity due to polar molecules or bound ions. For Part II see *Ceram. Abs.*, **18** [7] 190 (1939). H.E.S.

Effect of ultrasonic waves on colloid phenomena: V, Influence on thixotropy. I, Thixotropic systems with aluminum hydroxide. NAOYASU SATA AND NOBUZO NARUSE. *Kolloid-Z.*, **86**, 102–106 (1939).—The influence of ultrasonic waves upon thixotropic systems of Al_2O_3 was investigated. The coagulation period of a thixotropic system shows a definite aging phenomenon, and this coagulation period progresses after the preparation of the system, i.e., after the electrolyte addition, to reach a limit value after 1 to 2 weeks. Ultrasonic waves lengthen the coagulation time more than shaking by hand. From the drop in the viscosity of highly polymerized substances by ultrasonic wave radiations, it was concluded that these waves not only liquefy thixotropic systems but also disperse the aggregation of smaller particles; they may, therefore, also change the hydration and dispersion of the adsorbed electrolytes and time necessary for coagulation. Temperature changes greatly influence (shorten) the coagulation time. The latter is also dependent upon the age of the system, the total time of shaking, and the frequency of the transformation of the thixotropic system. L.E.T.

Gas-volumetric semimicrodetermination of carbon. E. BERL AND W. KOERBER. *Ind. Eng. Chem., Anal. Ed.*, **12** [4] 245–46 (1940).—Illustrated. F.G.H.

Hue, saturation, and lightness of surface colors with chromatic illumination. DEANE B. JUDD. *Jour. Research Nat. Bur. Standards*, **24** [3] 293–333 (1940). R.A.H.

Industrial minerals. SAMUEL H. DOLBEAR. *Eng. Mining Jour.*, **141** [2] 95–96 (1940).—D. briefly considers the 1939 output and consumption of andalusite, sillimanite, asbestos, barite, bentonite, borax, chromite, crushed stone, diamonds, feldspar, lime, magnesite, mica, Portland cement, potash, sulfur, bauxite, and fluorspar. J.L.G.

Investigations of protective colloids. E. SAUER AND W. ALDINGER. *Kolloid-Z.*, **85**, 295–316 (1938).—The adsorption of protective colloids, such as gum arabic, gelatine, and dextrine, was investigated on clay suspensions of uniform particle size; the separation of the suspension from the surplus protective colloid was accomplished by centrifuging. The sedimentation volume shows characteristic regularities which allow conclusions to be made

concerning the structure of adsorption layers. The cataphoretic migration velocity of the clay particles, in the presence of protective colloids, takes on the migration velocity of the added colloids. The concentration of the protective colloid with which this condition is reached corresponds to the break in the sedimentation-volume curve. Considerable differences exist between the investigated colloids regarding adsorbed amounts, kind of water fixation, flocculation, etc. The adsorption of a hydrophilic colloid does not cause unconditional protection. If the latter is accomplished, then the most active colloid is the one which is adsorbed in the largest quantities. The limit of concentration at which protective action is reached is in no way indicated in the adsorption isotherms of the sedimentation-volume curve or in the cataphoretic migration-velocity curves. 13 diagrams, 7 tables. L.E.T.

Mechanism of the hardening of clay-sodium silicate mixtures. W. R. MORGAN, W. L. PESKIN, AND S. J. KRONMAN. *Jour. Amer. Ceram. Soc.*, **23** [6] 170–73 (1940).

Melting point of high-purity silicon. M. L. V. GAYLER. *Nature*, **142** [3593] 478 (1938).—G. found a melting point of 1415° ±2°C. for 99.93% silicon. Hoffman and Schulze (*Ceram. Abs.*, **17** [10] 342 (1938)) found a melting point of 1411° ±2°C. for 99.89% silicon and 1409° ±2°C. for commercial (98%) silicon. G.'s material analyzed as follows: insoluble 0.01, Al 0.02, Fe 0.02, Ca 0.02, and silicon, by difference, 99.93%. J.L.G.

Nessler cylinders of lead glass. T. MCLACHLAN. *Analyst*, **64**, 669 (1939).—Analysts are warned of the high results which may be obtained through the use of lead glass Nessler tubes in making colorimetric lead determinations. B.C.R.

Precipitation of aluminum hydroxide and its solubility in ammonia. E. B. R. PRIDEAUX AND J. R. HENNESS. *Analyst*, **65** [767] 83–87 (1940).—The precipitation of $Al(OH)_3$ occurs at pH 4 in sulfate solutions and at pH 6.5 in chloride solutions due to the tendency of the latter to hydrolyze; the presence of sulfates tends to discharge the positively charged micelle and precipitate the Al as a basic salt. In precipitating with NH_3, the pH is controlled by the relative amounts of NH_4Cl and NH_4OH used, and for any given mixture the $H^+ = NH_4Cl/NH_3 \times 10^{-9.5}$. In a series of solutions in which the NH_4Cl:NH_3 ratio was varied in steps from 8 to 512, the calculated and observed pH values agreed to within 0.3. The pH varied from 8.6 to 6.8 with the maximum buffer effect occurring at pH 4.6. The effect of NH_4Cl in precipitating Al is principally to accelerate the formation of nuclei; a small excess of ammonia aids coagulation of the precipitate. B.C.R.

Quantitative spectrochemical analysis by measurement of relative intensities. E. K. JAYCOX AND A. E. RUEHLE. *Ind. Eng. Chem., Anal. Ed.*, **12** [4] 195–96 (1940).—A method which combines flexibility of application with the improved precision resulting from modern methods of photometry is described. Applications have been made to samples in which the main component is lead, aluminum, iron, copper, nickel, and the alkaline earth oxides, with an average precision of 50 to 100 parts per thousand of the element determined. Illustrated. F.G.H.

Spectrochemical analysis. A. E. RUEHLE. *Bell Lab. Record*, **17** [7] 202–205 (1939).—Elementary concepts of spectroscopy are briefly reviewed, and specific examples of spectrochemical analysis are given with quantitative and qualitative illustrations. See *Ceram. Abs.*, **18** [7] 191 (1939). P.S.D.

Velocity of oxidation of CoO to Co_3O_4. GERMAINE CHAUVENET. *Compt. Rend.*, **209** [24] 886–87 (1939).—The oxidation of metallic Co follows a parabolic law both in transformation from the metal to the lower oxide and from the lower to the higher oxide; the latter takes place between 500° and 750°C.; at this temperature, Co_3O_4 ceases to be stable. The activation energy was determined to 23,950 cal. The number of grams of CoO transforms at 760 mm. Hg. with a constant surface of s cm.^{2}, i.e., $n = 571se^{-11975/T}\sqrt{t}$ gm. in t hr. and at the absolute temperature, T. M.H.

Viscosity-temperature relationship in molten substances. E. JENCKEL. *Z. Physik. Chem.*, **A184** [4] 309–19 (1939).—The general form of the viscosity-temperature curve is derived from experimental data. Plotted against reciprocal temperature, the logarithm of the viscosity ($\log \eta$) shows a straight line with lower viscosities but rises rapidly with higher viscosities. J. assumes that, in the straight line section of the curve, the viscous flow is proportional to the active molecules and that in the curved sharp rising part a single active molecule cannot flow because it is surrounded by a heavy wall of inactive molecules; here, therefore, only several adjoining active molecules may begin to flow. With this conception, the following formula was advanced:

$$\log \eta = \frac{M \cdot Q}{RT} + \frac{MQ}{RT} \cdot x \cdot e^{-Q/RT} + \log A,$$

where Q, x, and A = the material constants, M = the modulus of Brigg's logarithms, and the expression $e^{-Q/RT}$ shows that fraction of a molecule which at least contains the energy Q. Measured values conform well with this formula. The change in the logarithms of the viscosity with reciprocating temperature is shown for 15 different substances, including $Na_2O \cdot 3SiO_2$, borax, B_2O_3, selenium, glucose, glycerine, etc. The viscosity curves for these materials at high viscosity are exceedingly steep. L.E.T.

X-ray investigation of the transformation of γ-aluminum oxide into α-aluminum oxide. O. E. GORBUNOVA AND L. I. VAGANOVA. *Trudy Tsentral. Nauch.-Issledovatel. Lab. Kamnei Samotsvetov Tr. "Russkie Samotsvety,"* **1938**, No. 4, pp. 66–67; *Khim. Referat. Zhur.*, **2** [5] 31–32 (1939); *Chem. Abs.*, **34**, 2228 (1940).—It was determined from Debye diagrams that the powder obtained by roasting the NH_4 alums at 1100° consists exclusively of the γ-modification of Al_2O_3, and the powder obtained by roasting at 1200° consists exclusively of the α-modification. The Debye diagrams of the powder roasted at 1150° show lines of both modifications. The transformation of the γ-modification of Al_2O_3 into the α-modification takes place at 1150° to 1200°.

BOOKS AND SEPARATE PUBLICATION

Electrolytic Recovery of Antimony from Antimonial Gold Ores: Metallurgical Division Progress Report No. 37. J. KOSTER AND M. B. ROYER. *U. S. Bur. Mines Repts. Investigations*, No. 3491, 19 pp. Free. R.A.H.

Fineness of Solids and Its Technological Importance. ALFRED H. M. ANDREASEN. *Ingeniørvidenskab. Skrifter*, No. 3, 71 pp. (1939); *VDI-Forschungsheft*, No. 399.—A. defines fineness in 1/cm. as $1/k$, with k being the average particle size, and develops mathematical equations to find k from weight, area, volume, etc. He gives practical methods, e.g., a count and weigh method, using the microscope for particle sizes between 5 and 500 μ, screen analysis down to 50μ, and several sedimentation analyses. The technical applications (homogeneity, porosity, paints, dust formation, and abrasives) are described. The importance of particle size for chemical reactions is discussed. Methods of changing coarse particles into fine ones and vice versa and of separating defined particle sizes are given. A bibliography is included. J.M.N.

Science since 1500. H. T. PLEDGE. H. M. Stationery Office. Price 7s 6d. Reviewed in *Times Lit. Supp.*, 39 [1984] 61 (1940).—P. treats in detail the stages of development of science from the 16th century to the present. Regional influence and that of personal contact are considered, together with the various inventions which made progress possible, including the contributions of glass. The interrelationship of the modern sciences is outlined. A bibliography is included. Illustrated. K.W.W.B.

PATENTS

Composition of matter and method of making. I. E. MUSKAT (Pittsburgh Plate Glass Co.). U. S. 2,199,710, May 7, 1940 (Nov. 26, 1937).—A method of preparing substantially dry, substantially unagglomerated, finely

divided calcium carbonate having an average particle size not in excess of 1 micron from an aqueous slurry containing the carbonate comprises mixing a substantial quantity not in excess of about 2% by weight of finely divided sulfur therewith, calculated upon the weight of calcium carbonate, the average particle size of the sulfur being not in excess of that of the calcium carbonate, and drying the mixture.

Composition of matter and method of making. I. E. MUSKAT (Pittsburgh Plate Glass Co.). U. S. 2,199,711, May 7, 1940 (Nov. 26, 1937).—A method of preparing a substantially dry, substantially unagglomerated, finely divided pigment having an average particle size not substantially in excess of 1 micron from an aqueous slurry containing the pigment comprises mixing a substantial quantity not in excess of about 2% of finely divided sulfur therewith, calculated upon the weight of the pigment, the average particle size of the sulfur being not in excess of that of the pigment, and drying the mixture.

Manufacture of:

Antimony trioxide pigments. KURT SCHIRRMEISTER (I. G. Farbenind. A.-G.). U. S. 2,200,478, May 14, 1940 (Feb. 2, 1939).

Beryllium compounds from beryllium earths. GES. ZUR VERWERTUNG-CHEMISCH TECHNISCHER VERFAHREN AKT.-GES. AND R. S. OPATOWSKI. Brit. 520,167, May 1, 1940 (Oct. 13, 1937).

Compositions of lead and its oxides. RICHARDSON CO. Brit. 519,332, April 3, 1940 (June 27, 1938).

Soluble alkali chromates. A. E. VAN WIRT (Imperial Paper & Color Corp.). U. S. 2,199,929, May 7, 1940 (Feb. 9, 1938).

Titanium dioxide pigments. A. G. OPPEGAARD AND C. J. STOPFORD (Titan Co., Inc.). U. S. 2,200,373, May 14, 1940 (June 7, 1939).

Preparing white lead. E. D. TURNBULL (Glidden Co.). U. S. 2,198,641, April 30, 1940 (Jan. 19, 1938).

Zinc oxide. H. M. CYR (New Jersey Zinc Co.). U. S. 2,200,873, May 14, 1940 (Nov. 27, 1935).

General

Air pollution and its problems. ALLAN C. MONKHOUSE. *Chem. & Ind.*, 38 [25] 596–600 (1939).—M. discusses the pollution of air due to gases, vapors, and dusts. The effect of the discharge of dusts from plants at a high level, such as a tall chimney, or at a low level, such as the windows, is described. G.R.S.

Antidotal rocks and silicosis. F. BREMNER. *Can. Mining Jour.*, 60 [10] 589–95 (1939).—Investigators have concluded that various rock dusts, when present or mixed in large proportions with free silica, have a modifying or antidotal effect upon the reaction of the latter on the lungs. It is difficult to predict the relative harmfulness of various dust mixtures containing free silica because of insufficient available knowledge of the nature of the protective materials and their manner of operation. Reasons suggested for this antidotal action have been dilution, flocculation, and, particularly in regard to metallic aluminum, the formation of an aluminous coating on the quartz particles. B. performed experiments under conditions comparable with those existing in body fluids. Results show that (1) many aluminous rock dusts can reduce the solubility of quartz markedly when mixed with it in equal proportions; (2) dialyzable alumina may be readily leached from many aluminous rocks and mineral dusts under body fluid conditions, and this alumina can form stainable aluminous coatings on fractured quartz surfaces; (3) the formation of this is the most important factor in reducing the true rate of solution of quartz particles; (4) the modifying effect of these dusts on the action of free silica in the lungs is probably chiefly due to their coating ability; (5) the maintenance in body fluids of a satisfactory coating depends on the presence, locally, of a surplus of leachable hydrated alumina; (6) these dusts are not recommended as protector dusts when a more concentrated and active form such as metallic alumina is available. G.M.H.

Detection of toxic gases and vapors in industry. R. B. VALLENDER. *Chem. & Ind.*, 58 [15] 330–33 (1939).—The sense of smell and the behavior of animals are both unreliable as general methods for detecting the presence of traces of toxic gases in industrial atmospheres. The need for simple rapid semiquantitative tests, sensitive to very low concentrations of gases and vapors, is pointed out, and the suitability of existing methods of gas determination is discussed. V.'s investigation carried out to develop a series of suitable tests for the commonly occurring gases and vapors is described. G.R.S.

Dust control. B. F. MORRIS. *Factory Management & Maintenance*, 98 [3] 82–83 (1940).—M. describes the dust controls which have protected workers in a battery-manufacturing plant from dust hazards to such an extent that there has been no case of lead poisoning in five years. Illustrated. J.L.G.

Effect of bismuth therapy on latent plumbism. E. EPSTEIN. *Arch. Dermatol. & Syphilol.*, 41, 38–41 (Jan., 1940).—The cases of a painter and a smelter worker are presented. Signs and symptoms of lead poisoning in both patients followed the administration of bismuth in the treatment of a syphilitic infection. E. suggests that bismuth may replace the lead stored in the bones and bring on the mobilization of lead, with the development of such symptoms as cramps and a lead line. Prophylactic treatment of lead poisoning in those exposed to the influence of the metal may decrease the incidence of untoward reactions following bismuth therapy. F.S.M.

Electron diffraction patterns of silica and alumina hydrate. ANON. *Bell Lab. Record*, 18 [8] 240 (1940).—Silicosis is completely prevented if there is as little as one-hundredth as much aluminum dust as silica in the air breathed. This preventive action has been ascribed to an extremely thin aluminum compound deposited on the surface of the silica particles. Electron diffraction patterns are shown of (1) thin films of silica previously exposed to aluminum and water at body temperatures and containing this thin film, and (2) silica alone. P.S.D.

Employability of the silicotic. VOYTA WRABETZ. *Ind. Medicine*, 7, 405–10 (July, 1938).—Increasing knowledge of silicosis has remedied the situation of several years ago when many employees were discharged and applicants were rejected on account of evidence of early silicosis, and large sums of money were paid for compensation. It is now known that many workers aged 40 to 50, who have worked for 20 to 30 years in massive concentrations of silica dust, are doing hard manual labor with no appreciable slowing down of efficiency. Removal from or continuation of work will make little difference in the progress of the disease. The Wisconsin law provides that an employer who discharges an employee who has a nondisabling silicosis and who can safely be retained in a particular employment shall be liable for an amount (not exceeding $3500) to rehabilitate such an employee. This provision is designed to discourage the promiscuous discharge of silicotics who are fully able to work. If tuberculosis is present with silicosis, naturally the same rules cannot apply. The tuberculous worker must not be exposed to dust. Re-examination of workers and the decrease of claims filed since these rules were adopted have confirmed their practicability. Similar recommendations were made by the National Silicosis Conference. W., who is Chairman of the Industrial Commission of Wisconsin, urges uniformity of interpretation of physical examinations. He states that Wisconsin's experience has taught that silicosis is by no means the serious problem which many persons believe it to be and that, if the problem is approached with the exercise of common sense and careful study and men are kept at work and examined periodically for complications, neither

will the cost be out of line with the cost of accidental injuries nor will the problem be one of undue difficulty. The continued employment of able silicotic workers, together with the control of silica dust concentrations, will cause the ghost of silicosis to disappear into thin air, as it already has to a large degree in Wisconsin. F.S.M.

Fundamental principles of segregation. R. L. BROWN. *Glass*, **16** [11] 422 (1939).—The principal factors causing segregation are size, shape, density, and distribution. The coefficient of friction, surface roughness, and moisture content, however, also have some effect. Twenty-two references are given. B.C.R.

History of the Bowmans. O. O. Bowman and his sons, W. J. J. and R. K. Bowman. ANON. *Bull. Amer. Ceram. Soc.*, **19** [5] 175–77 (1940).

Lead danger and its prevention. ANON. *Gesundh.-Ing.*, **62** [2] 28 (1939).—Less lead enters the body by breathing than by the hands. Lead danger can be decreased by good ventilation of the workrooms; prohibiting eating during working hours; thorough cleaning of hands, face, mouth, and teeth before rest pauses and after work; supplying sufficiently large washrooms with running hot water; using efficient cleaning material; extending the rest pauses for thorough cleansing of the body; and periodical medical examinations. W.D.K.

Lead poisoning and silicosis. H. R. ROGERS AND T. DYMOCK. Discussed before Conference of Works Inspectors and Managers, held under the auspices of the National Council of the Pottery Industry, Hanley, Dec., 1937; abstracted in *Pottery Gaz.*, **63** [728] 260 (1938). L.S.

Lighting and air-conditioning improve draftsmen's efficiency. ANON. *Occupational Hazards*, **2**, 31 (March, 1940).—Last summer the Detroit Edison Co. found that its draftsmen were getting out 8988 "work units" in 5008 man-hours. When the draftsmen moved into a new windowless building completely air-conditioned and illuminated electrically with 50 foot-candles at the drafting table top, they required only 3872 man-hours to do 10,474 work units, a 51.4% increase in efficiency. Work no longer becomes smudged by hot sticky fingers; the tired eyes of tired men no longer bring about time-consuming errors. F.S.M.

1940 marketing opportunities: Ceramics and glass. Clay products. REXFORD NEWCOMB, JR. JAMES M LANGE. *Ind. Marketing*, **25** [1] 15–16 (1940). F.E.S.

Occupational disease claim held not barred by Statute of Limitations. ANON. *Occupational Hazards*, **2**, 14 (March, 1940). F.S.M.

Osteomyelitis develops from brass particles in clothes. ANON. *Occupational Hazards*, **2**, 15 (March, 1940).—An award was granted to the claimant for temporary and permanent disability resulting from the amputation of one leg. F.S.M.

Ophthalmologist and the Workmen's Compensation Law. J. H. DELANEY. *Penna. Med. Jour.*, **43**, 645–47 (Feb., 1940).—Pennsylvania and 23 other states are urged to establish uniform standards and methods of evaluating visual efficiency and visual loss. F.S.M.

President's address. A. I. ANDREWS. *Bull. Amer. Ceram. Soc.*, **19** [5] 173–74 (1940).

Standards for respirators. W. H. LEMBERG. *Safety Eng.*, **79**, 30 (Jan., 1940). F.S.M.

Toxicity of organic solvents. T. MCCLURKIN. *Chem. & Ind.*, **58** [15] 339–42 (1939).—Acute and chronic poisoning by the vapors of organic solvents is described, and examples of poisoning in man are given. Not only the danger of exposure to high concentrations but also the less frequently understood danger of exposure to low concentrations is stressed. G.R.S.

Workmen's compensation and occupational disease laws in the Commonwealth of Pennsylvania. M. BEHREND. *Penna. Med. Jour.*, **43**, 1820 (Oct., 1939).—The history of the Workmen's Compensation Act from 1915 to 1939 is discussed. B. mentions the controversy existing between the physician and the insurance company regarding the right of the injured man to choose his physician. He advocates a universal workmen's compensation law for the injured to be accomplished through a Federal Act. Although there are 672,000 employees exposed to industrial disease hazards in Pennsylvania, less than 20 cases have been posted with the compensation board. This is in part due to the ignorance of the laborers and to the fact that the adoption of claims for occupational diseases is optional with the companies. F.S.M.

BOOKS AND SEPARATE PUBLICATIONS

Lead Poisoning: I; II, Precision Method for Lead. Edited by R. L. HOUTZ. *Penna. Dept. Labor & Ind., Safe Practice Bull.*, No. 52.—Precision tests for extremely small amounts of lead developed at the Jefferson Medical College Hospital, Philadelphia, are given. The method, a modification of the diphenylthiocarbazone type, is carefully described, and the apparatus is illustrated. F.S.M.

Physical Examinations in the Iron and Steel Industry. ANON. American Iron and Steel Institute, New York, Jan., 1940.—This study was undertaken with the sponsorship of the Industrial Relations Committee of the American Iron and Steel Institute for the purpose of ascertaining what is being done in the matter of physical examinations in a representative sample of the industry. Personal visits were made to 18 various sized companies, widely distributed geographically, during the late summer of 1939. No definite conclusions or recommendations are offered, but a brief summary of the data is given in the form of charts. Physical examinations of all new applicants for work are made by the plant's physician in all of the 18 companies. Eleven companies recognize only one grade of applicant, two recognize 3 grades, and two classify into 4 grades. Defects of vision head the list of defects temporarily accepted by some companies pending treatment or correction and also the list of causes for rejection. Of the defects most commonly found, hernia is most frequent. One large company states that the number of rejections of new applicants does not exceed 5%. Among the 18 companies, only 3 of the smaller do not have any program of re-examination. Three have programs covering all of their mill workers (at varying periods, 1 to 3 years), and 12 companies re-examine workers in certain occupations where unusual hazard to health or body may exist, such as transportation workers and those with exposures to silica, lead, benzol, etc. X rays are made of all employees in three companies, and eight others make the test where there is evidence or suspicion of disease; four make them of certain groups, and four do not make or require these tests. The average figure for absenteeism of about 6 days for all employees is misleading, since it does not include the many days lost through cases which lasted less than seven days (these figures were taken from sick-benefit records). F.S.M.

Pneumoconiosis (Silicosis). Story of Dusty Lungs. Preliminary Report. L. G. COLE AND W. G. COLE. John B. Pierce Foundation, New York, 1940. 52 pp., appendix, and index. F.S.M.

Use of Respiratory Protective Devices Under Abnormal Air Pressure. F. E. GRIFFITH AND H. H. SCHRENK. *U. S. Bur. Mines Repts. Investigations*, No. 3488, 9 pp. Free.—The use of oxygen breathing apparatus and gas masks under pressure is described. R.A.H.

PATENTS

Ceramic-to-metal seal. HANS PULFRICH (Canadian General Electric Co., Ltd.). Can. 386,695, Feb. 6, 1940 (Nov. 24, 1937). Can. 386,697, Feb. 6, 1940 (Jan. 25, 1938). G.M.H.

Ceramic and metallic material uniting method. HANS PULFRICH AND RICHARD MAGNER (Canadian General Electric Co., Ltd.). Can. 386,696, Feb. 6, 1940 (Dec. 7, 1937). G.M.H.

Making a tight union between pieces of glass or glazed ceramic materials. FIDES GES. FÜR DIE VERWALTUNG UND VERWERTUNG VON GEWERBLICHEN SCHUTZRECHTEN M.B. H. Fr. 850,362, Feb. 16, 1939. D.A.B.

OFFICIAL PERSONNEL OF DIVISIONS, 1940–1941

	Art	Enamel	Glass	Materials and Equipment	Refractories	Structural Clay Products	White Wares
Trustee	L. E. Barringer	J. E. Hansen	D. E. Sharp	H. B. DuBois	J. D. Sullivan	A. F. Greaves-Walker	E. H. Fritz
Chairman	H. S. Nash	J. D. Tetrick	W. R. Lester	B. T. Bonnot	J. B. Austin	H. Z. Schofield	Harry Thiemecke
Vice-Chairman	K. E. Smith		A. K. Lyle	W. H. Emerson	Gilbert Soler	J. H. Isenhour	
2nd Vice-Chairman			W. C. Taylor				
Secretary	C. C. Engle	D. G. Bennett	S. R. Scholes	S. S. Cole	R. S. Bradley	L. R. Whitaker	R. Russell, Jr.
Society Nominations A.....	M. M. French	B. T. Sweely	F. C. Flint	W. R. Malkin	G. A. Bole	R. L. Stone	L. E. Thiess
Society Nominations B.....	C. C. Engle	R. R. Danielson	W. M. Clark	H. R. Straight	S. M. Phelps	T. W. Garve	D. C. Zimmer
Division Nominations	Ruth Canfield A. A. Ayars	H. G. Wolfram	A. N. Finn				
Papers and Program	W. A. Weldon Carlton Atherton J. P. Thorley	R. L. Fellows	A. K. Lyle W. C. Taylor	S. S. Cole J. R. Kauffman R. Buchholz	C. L. Thompson W. R. McLain G. S. Diamond	H. D. Foster F. E. Lobaugh J. E. Rankin	F. C. Henderson Howard Failmezger C. G. Harman
Membership	H. E. Marley H. H. Sanders	Karl Kautz	C. B. Delgado	J. T. Robson	C. A. Freeman	J. H. Stewart	G. J. Bair
Standards	A. E. Baggs	F. W. C. Hutchison	G. W. Morey	W. H. Vaughan	P. S. Dear	H. C. Plummer	J. H. Koenig
Research	H. P. Bopp	R. J. Whitesell	N. W. Taylor	J. F. McMahon	D. W. Ross	Frederick Heath, Jr.	J. R. Beam
Data	Marion Fosdick P. E. Cox	P. C. McCollom	A. E. Badger	R. G. O'Meara	P. G. Herold	H. G. Schurecht	G. A. Loomis
Rules	Theodore Lenchner	G. H. Spencer-Strong	A. N. Finn	J. E. Eagle	R. B. Sosman	G. H. Duncombe, Jr.	K. E. Stettinius
Councillors	C. M. Harder A. E. Baggs	W. H. Pfeiffer R. D. Cooke	L. C. Roche F. C. Flint	V. V. Kelsey F. E. Finch		C. R. Austin T. W. Garve	F. P. Hall Karl Schwartzwalder
Exhibitions	Ruth Randall	*Bibliography* J. E. Rosenberg	R. M. Curts				
Industrial Management	F. H. Rhead				G. B. Remmey		